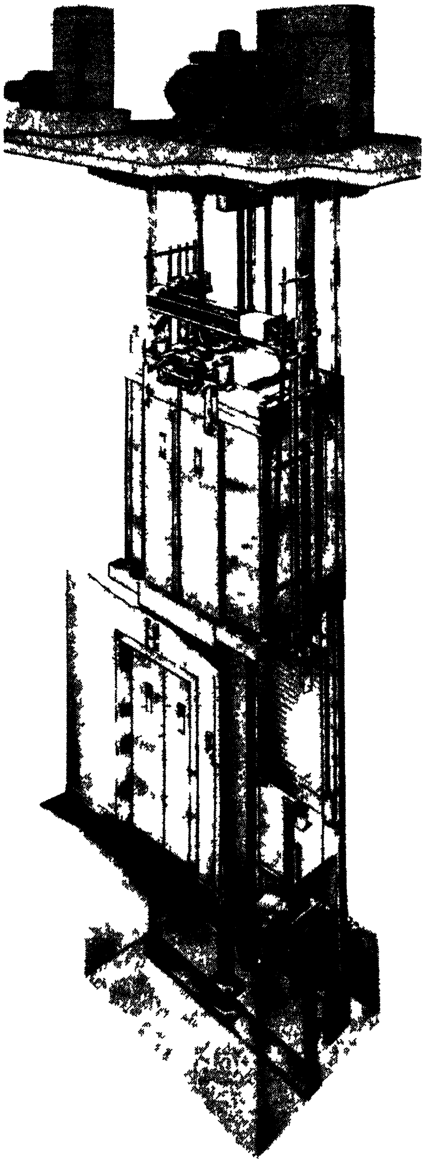
# ELECTRIC LIFTS



Modern High Speed Gearless
Variable Voltage Lift
(*Express Lift Co Ltd*)

# ELECTRIC LIFTS

A MANUAL ON THE CURRENT PRACTICE IN THE DESIGN, INSTALLATION, WORKING, AND MAINTENANCE OF LIFTS

BY

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# PREFACE TO FOURTH EDITION

IN this edition many illustrations which appeared in the earlier editions have been replaced by those of up-to-date equipment, and a number of additional illustrations of new equipment are also included. A great deal of the earlier information has been rewritten to conform with modern practice, and there is new data, particularly in the chapters on "Accommodation" and "Controllers."

R. S. P.

LONDON
1957

# PREFACE TO FIRST EDITION

MANY years have elapsed since the publication of a book dealing with British lift practice, and in view of the rapid development of the industry during recent years the Author feels that the present time is opportune for the production of a work describing modern lift equipment and methods.

The idea originated during the reading of the Author's paper entitled "Modern Electric Passenger Lifts" before the Institution of Post Office Electrical Engineers in 1935. Mention was made, during the discussion, of the lack of published information on the subject, whilst added weight was given to these remarks by subsequent talks with members of some of the lift manufacturing firms.

One of the difficulties encountered in preparing the material was the use, by various authorities interested in lift installation, of different terms for the same items of equipment and methods of control. The publication of the *Code of Practice for the Installation of Lifts and Escalators* by the Building Industries National Council, however, did much to remove these difficulties, and the Author decided to adopt, as far as possible, the terms recommended for general use by this Council. In

addition, most of the safety measures embodied in the Code have been carried into this work.

A great deal of the information has been obtained from notes made by the Author during the past few years, whilst the origin of other details has been duly acknowledged in the text.

The value of the book has been considerably increased by the generous assistance rendered by the leading British lift and motor manufacturers who, in addition to supplying information regarding their equipment, were kind enough to loan blocks or photographs from which many of the illustrations have been prepared. In this connexion the Author desires to take this opportunity of thanking the following firms: British Thomson-Houston Co., Etchells Congdon & Muir, Express Lift Co., J. & E. Hall, Marryat & Scott, Metropolitan Vickers Electrical Co., R. J. Shaw, Waygood-Otis, Wm. Wadsworth, and in particular, Mr. W. Wood, Chief Electrical Engineer of the last-named firm, who checked a great deal of the material in Chapter XV and offered valuable suggestions. In preparing Chapter IV the Author gratefully acknowledges help received from British Ropes, Ltd., which firm loaned blocks for many of the illustrations in this chapter.

In conclusion, the Author wishes to state that, although employed by the Post Office, the practices described in this book are not necessarily those adopted by the Post Office Engineering Department. Obviously, however, many of the details are the result of experience gained during the erection and maintenance of Post Office lifts.

R. S. P.

LEEDS
1938

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# CHAPTER I

## DESIGN AND TRAFFIC ANALYSIS

To provide the best possible lift service in a building, consistent with cost and any building restrictions, it is necessary that full consideration be given to the problem, and to do this all the available data regarding the type of building and its occupants should be closely studied. There are three main types of lift, namely *passenger*, *goods*, and *service*. Passenger lifts are those designed primarily for passenger service, goods lifts are mainly for the transport of materials, but may be required occasionally to carry passengers, whilst a service lift is so constructed as regards size, or otherwise, that it is impossible for passengers to enter the car, and hence goods only are carried. In any particular building it will soon be evident which of these types will be necessary, and some consideration will now be given to the selection of lifts for these various purposes.

### PASSENGER LIFTS

The total capacity of passenger lifts required in any building to give a certain grade of service is determined by the number of occupants and the number of visitors who will be expected to utilize a lift service, and both vary considerably with the type of building. The density of the visitors and occupants will be great for restaurants and theatres and less for offices, hotels, and flats. In this country a large number of buildings are of such size and nature that very little difficulty will be experienced in deciding that one passenger lift will give adequate service. It should be remembered, however, that it is often preferable to install two small lifts if, on the grounds of capacity alone, it is thought that a single lift will have to be of a fairly large capacity, say 3 000 lb. Two small lifts of 1 500 lb. capacity each will give better service than one large lift, the latter probably having been designed to cater for the maximum number of passengers at the periods of peak loading. Consequently, this lift will be running comparatively lightly loaded for most of the day, with a resulting decrease in

efficiency and increase in running costs. On the other hand, with two small lifts, adequate service could probably be maintained during the greater part of the day with one lift, the second being brought into service during peak loads. The advantages to be gained by installing two smaller lifts often outweigh the extra initial outlay.

Having decided that the number of occupants and floors (usually not less than three floors for passenger service) justify the provision of a lift, we then necessarily have to prepare a specification detailing the various features required. Although it is desirable from the safety point of view that certain items should be specified, the general type of passenger lift in this country is now so well established that most of the reputable lift firms will design and supply a perfectly satisfactory and safe lift if provided with only the main requirements such as well sizes, power supply characteristics, contract speed, type of control, and contract load. The contract speed and the contract load are the maximum values as specified in the contract of purchase. The essential details can confidently be left to any British firm of repute if the buyer is not in a position to furnish a comprehensive specification. Those authorities, however, who draw up their own specifications in order to ensure that they obtain, even in detail, what they require, almost all specify certain main items of equipment and conditions to which they must conform. Extracts from a typical high-class specification are given here as a guide.

**Specification.** *Lifting Ropes.* Minimum number two, usually Lang's lay and having a factor of safety of not less than 10. No ropes to be lengthened or repaired by joints. Ropes to be fastened to the car frame so that all strain is removed from the car.

*Clearances for Car and Counterweight.* (Minimum values for these as stated in Chapter XII.)

*Sheaves and Pulleys.* Cast iron or steel of disc construction and of such diameters that none is less than forty times the rope diameter. Frequently, larger size sheaves and pulleys than this are specified in order to secure long rope life. Any pulley or sheave shaft fitted between dead eyes to be reduced in diameter at the points of entry. The angle of the sheave groove is usually between 40° and 35°.

*Car*. General finish to suit the customer but the minimum thicknesses for panelling and framing of wooden cars are often specified as $\frac{3}{4}$ in. and $1\frac{1}{2}$ in. respectively. Removable panel to be fitted either in the roof or in the side, the latter if two lifts run side by side in the same well. Car to be adequately ventilated and artificially lighted and inside height to be not less than 6 ft. 6 in.

*Gates or Doors*. Gates for both car and landing openings to be of the overhung collapsible pattern and of the close picket type. The landing gates or doors to be mechanically and electrically interlocked and the car gate or door electrically interlocked only. Every landing door to be provided with a "fire-resisting" vision panel.

*Guides*. Of steel, either round or tee-section (the latter specified for car speeds above 200 ft. per min.). Round guides to be mounted on steel backings.

*Gearing*. Worm and worm-wheel type. Worm of steel, forged solid with shaft, and wheel to consist of renewable phosphor-bronze rim shrunk and bolted to a cast-iron centre.

*Safety Devices*. Terminal limit switches to stop the car automatically at the terminal floors. In addition, final limit switches to be fitted. Safety gear to be provided underneath the car and also under the counterweight if there is accommodation under the pit. Instantaneous type safety gear for speeds up to 200 ft. per min., and either gradual wedge clamp type or flexible guide clamp type for higher speeds. Buffers to be fitted under both car and counterweight, helical or volute spring buffers for speeds up to 300 ft. per min. and oil buffers for higher speeds.

*Wiring*. All electrical wiring to be in accordance with the Regulations issued by The Institution of Electrical Engineers.

*Machine Room*. To be adequately lighted and ventilated and at least 7 ft. clear in height.

*Counterweight*. Sections to be of cast iron or cast iron weighted with lead and tie rods to pass through holes in all sections.

*Control*. Controller reversing switches to be mechanically and electrically interlocked. It must be impossible to operate the lift if any landing gate or car gate is open. It must be impossible to interfere with the normal travel of the lift by

means of the landing buttons when the car is in motion. Controller interlocks to be fitted on the safety gear and on the brake hand release lever when this is fitted.

**Speed.** When determining a suitable car speed, the height of the building, distance between stops and quality of service desired must all be considered. The higher the car speed the better the resulting service, but it must be remembered that the cost of a lift increases as the contract speed is raised. If a large amount of interfloor traffic is anticipated, the car speed should not exceed about 200 ft. per min., otherwise most of the running time will consist of acceleration and retardation and the motor will not have sufficient time in which to travel for an appreciable distance at its full speed. In buildings of seven or eight storeys, where a fair amount of traffic from the ground to the upper floors is expected, speeds up to 400 ft. per min. are now common. A number of the larger buildings in this country having upwards of about ten storeys employ car speeds of up to 600 ft. per min. In America, however, several of the "skyscrapers" have upwards of fifty storeys, and speeds of 800 ft. per min. are quite common, whilst the larger of these buildings are equipped with lifts travelling at 1 400 ft. per min. These high speeds are only used for express service to the upper floors.

Car speeds are generally selected in relation to the number of floors served, and the usual practice in this country, for general office buildings, is as follows—

| No. of Floors | Car Speed in ft per min. |
|---|---|
| 2 | 100 |
| 3–4 | 100–150 |
| 5–6 | 200–300 |
| 7–9 | 300–400 |
| 10–12 | 400–500 |
| over 12 | 500–600 |

When installing a lift in an existing building, however, other factors such as the available top and bottom clearances may limit the lift speed.

**Size and Capacity of Car.** In deciding the approximate car size it is usual to allow 2 ft.$^2$ for each passenger and 3 ft.$^2$ for

the attendant for cars up to 1 500 lb. capacity. The internal height should be not less than 6 ft. 6 in. To calculate the size of the lift machine, the car loading must be known, and in arriving at this the average weight of each passenger is taken as 150 lb., but frequently $1\frac{1}{2}$ cwt. is used as a rough approximation.

**Type of Control.** When considering the method of control to be adopted, the type of building and of its occupants and the lift capital cost are the determining factors. For intermittent traffic an attendant is not justified, and an automatic form of control should be installed. On the other hand, when the traffic is likely to be fairly regular, better service may be maintained by employing a car attendant and adopting car switch control. If the traffic is intermittent for the greater part of the day, but definite peak periods are expected, such as in the early morning, at midday, and in the evening, it is advisable to install a dual form of control. With this control, the car is normally worked automatically by the passengers, but by an attendant and car switch control during the periods of heavy traffic. Where the extra cost is warranted, signal control or automatic collective control is adopted, and these are now becoming common practice.

**Lift Costs.** The cost of a lift depends upon the details of the specification on which the tender is based and also varies appreciably with different contractors. As with many other forms of engineering equipment the price quoted is governed to some extent by the nearness of the specification to the contractor's standard items and also just where the customer's particular requirement falls in his standard ranges. A specification may suit one contractor but not another and this will result in a considerable difference in prices. The tendered price will also depend upon the state of the contractor's order book at the time of tendering. The average 1956 prices for various typical lifts are shown in the table on page 6, but because of the above facts these may vary between 10 per cent below and 10 per cent above those quoted. They are for the provision and installation of lifts to a high-class specification by one of the reputable British firms, but do not include for any builder's work or for the provision of any well steel structure or enclosure that may be required.

TYPICAL 1956 LIFT COSTS

| Type | Travel in ft. | Floors Served | Load in lb. | Speed in ft. per min. | Control | Entrances | Cost |
|---|---|---|---|---|---|---|---|
| | | | | | | | £ |
| Service | 26 | 3 | 336 | 50 | Semi-Automatic | Collapsible steel shutter doors | 1 250 |
| Goods | 109 | 9 | 784 | 200 | Automatic | Manual gates | 4 100 |
| Goods | 13 | 2 | 3 360 | 100 | Automatic | Single entrance bi-parting power-operated doors | 4 200 |
| Goods | 13 | 2 | 3 360 | 100 | Automatic | Front and back entrances, bi-parting power-operated doors | 4 800 |
| Goods | 26 | 3 | 4 480 | 150 | Automatic | Single entrance bi-parting power-operated doors | 5 400 |
| Goods | 57 | 5 | 5 600 | 200 | Dual collective V.V. geared | Manual shutter type doors | 5 500 |
| Passenger | 73 | 5 | 1 680 | 200 | Dual | Manual gates | 4 200 |
| Passenger | 109 | 8 | 2 240 | 300 | Dual collective V.V. geared | Power-operated doors | 7 000 |
| Passenger | 112 | 9 | 2 240 | 500 | Dual collective V.V. gearless | Power-operated doors | 8 400 |

## LIFT SERVICE FOR LARGE BUILDINGS

The larger buildings require several passenger lifts to provide adequate service, and the problems associated with the design of such installations are much more complex than when a single lift will fulfil the requirements. Variations of speed, capacity, number and position of lifts are the main factors which effect the quality of service and the cost, and from the infinite number of possible combinations one must be selected which will best satisfy the requirements of the particular building with due regard to economics.

**Preliminary Considerations.** A lift installation is the result of joint efforts by the lift designer, architect, builder, and lift contractor, although in many cases the lift contractor combines the functions of lift designer, constructor and erector. The lift designer knows what he requires of the building, the architect is aware of the methods of best fulfilling these requirements, and the builder carries out the necessary structural work.

Close liaison between these three during all sketch plan and working drawing stages is often the difference between a costly and inferior installation, and one that is satisfactory in all respects. It is most unsatisfactory for an architect to reach the working drawing stages without having been made aware of the number and positions of the lifts and of the sizes of the wells and machine rooms or, on the other hand, for the lift designer

FIG 1 THREE INTERCONNECTED GEARLESS LIFTS
(*Express Lift Co Ltd*)

to be asked for this information at so late a stage and perhaps be requested that his lifts should suit some space on the drawings which has been left for this purpose.

The first matter for consideration is the positions to be occupied by the lift wells, the main requirements being that users will be able to pass quickly from the building entrance to the lifts and that the lift exits on the higher floors will be as near as possible to the centres of population of the floors. If the building has one main street entrance, the passenger lifts should be arranged adjacent to each other in a single

bank and conveniently situated with regard to the entrance. From the lift service aspect the bank should not be arranged in two sections, one on each side of a central staircase, which practice is sometimes adopted for appearance or to satisfy architectural requirements. With a single bank as in Figs. 1 and 2, a common machine room can be used and so simplify maintenance, it is easier to arrange lift interconnexion facilities

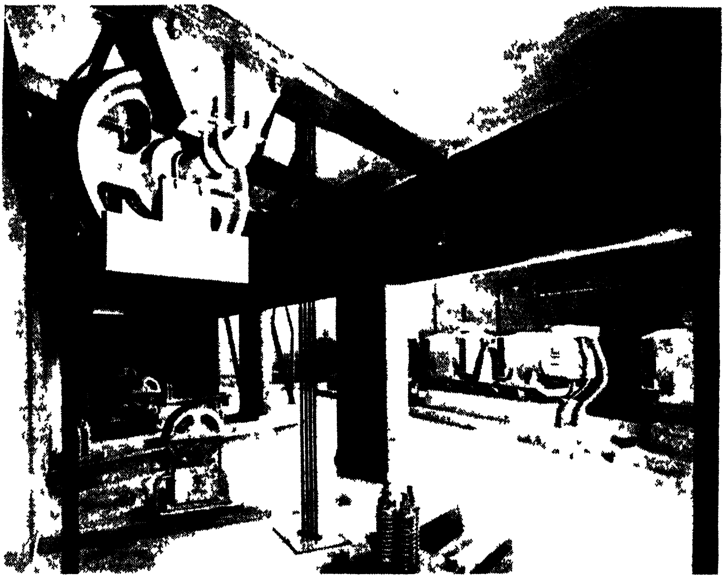


FIG. 2. MACHINE ROOM (LOWER LEVEL) OF LIFTS IN FIG. 1
(*Express Lift Co. Ltd.*)

and the resultant service is better than if the lifts are separated. If the building has two main entrances, two banks of lifts are necessary, the number in each bank being governed by the number of passengers that will be expected to use each entrance. Although the lift entrances are usually near the stairway, care should be taken in the design to ensure that persons intending to use the lifts are kept clear of those who wish to use the stairs, which are for floor to floor foot traffic and for use in an emergency.

**Grade of Service.** Consideration must next be given to the

quality of service it is desired to provide, and this depends upon the type of building, its rental value, or on the importance of its occupants. This quality of service is a measure of the speed with which passengers can be transported to their destinations and hence is determined by the sum of the time which the average passenger has to wait for the arrival of a lift and the time for the lift to reach the desired floor. The shorter these times the better will be the service provided. The maximum time a person may have to wait for a lift is termed the Waiting Interval (W.I.) and is the interval between the arrival of successive cars. This depends upon the Round Trip Time (R.T.T.) of each lift and on the number of lifts in the bank. The R.T.T. is the time which elapses between a lift leaving the ground floor and again arriving at that floor after making an average number of stops at the upper floors with an average number of passengers. It will be appreciated that it is possible to obtain the same grade of service with a large number of slow speed lifts as with a small number of high speed lifts, and economics will determine the best arrangement between these two extremes. A lift service which has a small W.I. and a large travelling time always appears to the user to be better than an equivalent service with a larger W.I. and a smaller travelling time, as a long wait tends to make a person impatient. For this reason it is usual to design for a waiting interval of from 20–60 seconds, the time selected depending upon the class of building.

No definite standards of service have yet been defined, but the qualities or grades of the lift services in different buildings may be assessed by comparing for each building the sum of the average time a person has to wait for a lift and the average travelling time. Hence the grade of service is determined by $\frac{\text{W.I.}}{2} + \frac{\text{R.T.T.}}{4}$. If there are $N$ lifts in the bank then W.I. $= \frac{\text{R.T.T.}}{N}$ and hence $\frac{\text{W.I.}}{2} + \frac{N \times \text{W.I.}}{4}$, or $\frac{\text{W.I.}}{4}(2 + N)$, is a measure of the grade of service. It may be noted that in a single lift installation $N = 1$ and W.I. = R.T.T. In this case the grade of service is measured by $\frac{3\,\text{W.I.}}{4}$. As an example

consider a bank of 4 lifts with an interval of 30 seconds between the arrival of each lift and in which the R.T.T. is 120 seconds. The average passenger would have to wait 15 seconds at the ground floor and his travelling time would be $\frac{120}{4} = 30$ seconds. The total waiting and travelling time would therefore be 45 seconds. From observations that have been made on many existing installations, it is reasonable to classify the grade of service as excellent, good, fair or casual if the value of $\frac{\text{W.I.}}{4}(2 + N)$ is not more than 45 seconds, between 45 and 55 seconds, between 55 and 65 seconds, or more than 65 seconds respectively. For any particular building a suitable time will be selected by the lift designer after he has considered closely the building and its occupants.

**Size of Car.** Usual car sizes for these large buildings are such that the car will accommodate 8, 10, 15 or 20 persons, the car floor area being determined as described in Chapter IX. In choosing the car shape it is desirable that the width should be not less than the depth so as to facilitate the rapid entry and egress of passengers. A car which is approximately square in shape is good practice.

Sometimes the car is required to be large enough to accommodate occasionally some special item of equipment and this will therefore indicate the size of car. In the absence of any such special requirement in designing for a bank of lifts, it is necessary to commence by choosing some arbitrary car size as a basis for consideration. For this purpose a 10-passenger car is suitable and subsequent investigation will then show whether a smaller or larger car would be preferable.

**Probable Number of Stops.** A round trip is composed of a number of factors and of these it is best to consider first the probable number of stops that will be made at the upper floors during the round trip. In the design of a lift service the probable conditions during the periods of heaviest traffic must be closely investigated. In office buildings the peak is generally in the morning when the building is being filled or during the evening when it is being emptied. If the lifts are designed so that they will satisfactorily clear the traffic during the peak period, the service will generally be adequate at all other periods.

Consequently it is necessary to estimate the probable number of stops that will be made during a trip in the peak period. The approximate numbers of persons employed on each floor must be known or estimated as well as the number of visitors likely to travel to the floors. A detailed study of these figures, together with a knowledge of the uses to which the building will be put, will enable the lift designer to estimate the probable peak periods and also the number of persons likely to travel to each floor during these periods. In many cases this information is sufficient for an experienced designer to estimate closely the probable number of stops during a trip in the peak period and where these are likely to be made, without more detailed study or calculation.

In the very large or high buildings an estimate by such means becomes more difficult and in these cases the formula developed below is used—

Let $N$ = the total number of passengers entering the car at the ground floor each trip during the peak period,

$P$ = the total population on all floors served during the peak period,

$P_a\ P_b\ P_c$ = population on the 1st, 2nd, 3rd, etc., floor served by the lift,

$n$ = number of floors served above the ground floor.

The probability that any passenger will leave the car at the first floor is $\frac{P_a}{P}$, at the second floor $\frac{P_b}{P}$, and so on.

The probability that the passenger will not leave the car at the first floor is $1 - \frac{P_a}{P} = \frac{P - P_a}{P}$

The probability that none of the passengers will leave the car at the first floor is $\left(\frac{P - P_a}{P}\right)^N$

Then for any particular floor the probability that no passenger will wish to leave the car is

$$\frac{1}{n}\left[\left(\frac{P-P_a}{P}\right)^N+\left(\frac{P-P_b}{P}\right)^N+\ldots\ldots+\left(\frac{P-P_n}{P}\right)^N\right]$$

Hence the probability that there will be a stop at any particular floor is

$$1-\frac{1}{n}\left[\left(\frac{P-P_a}{P}\right)^N+\left(\frac{P-P_b}{P}\right)^N+\ldots\ldots+\left(\frac{P-P_n}{P}\right)^N\right]$$

Therefore the average probability that there will be stops at $n$ floors is

$$n\left\{1-\frac{1}{n}\left[\left(\frac{P-P_a}{P}\right)^N+\left(\frac{P-P_b}{P}\right)^N+\ldots\ldots+\left(\frac{P-P_n}{P}\right)^N\right]\right\}$$

or the probable total number of stops $S_n$ is

$$n-\left[\left(\frac{P-P_a}{P}\right)^N+\left(\frac{P-P_b}{P}\right)^N+\ldots\ldots+\left(\frac{P-P_n}{P}\right)^N\right]$$

It follows that the expression within the brackets $\Big[\quad\Big]$ represents the probable number of landings at which no stop will be made.

If stops are always made at certain floors, e.g. the third and sixth, the corresponding terms are omitted from the formula which, in this example, then becomes

$$S_{n-2}=(n-2)-\left[\left(\frac{P-P_a}{P}\right)^N+\left(\frac{P-P_b}{P}\right)^N+\left(\frac{P-P_d}{P}\right)^N+\left(\frac{P-P_e}{P}\right)^N+\left(\frac{P-P_g}{P}\right)^N+\ldots\ldots+\left(\frac{P-P_n}{P}\right)^N\right]$$

and $S_n=S_{n-2}+2$.

If each floor has the same population i.e.

$$P_a=P_b=P_c\ldots\ldots=P_n=\frac{P}{n}$$

then the probable number of stops

$$S_n = n - n\left(1 - \frac{1}{n}\right)^N$$
$$= n\left[1 - \left(\frac{n-1}{n}\right)^N\right]$$

**Round Trip Time.** Having selected what might be a suitable car size (10 persons) and determined the probable number of stops, detailed consideration can next be given to the various factors comprising the R.T.T. during the busy period. The R.T.T. will be composed of times for opening and closing of doors, passengers to leave and enter the car, acceleration and retardation of the car near landings, running at contract speed, and for operations of the car switch, or push buttons.

**Door Operation.** The time required for opening and closing the doors depends upon the method of operation and on the type and width of the doors. With a 4 ft. entrance and two-speed power operated doors, in which the landing and car doors move simultaneously, the minimum time for opening and closing is about 4 seconds. If centre opening doors are fitted, these move a distance of only half the entrance width and hence the corresponding time is approximately 3 seconds. The doors should be as light as possible to facilitate quick operation.

Manually operated doors or gates are seldom fitted to-day on large passenger lift installations as the time wasted in operation is so great. Further, this time can vary considerably depending upon the particular person performing the opening and closing. The average time for manual opening and closing is about 6 seconds if the car and landing gates are coupled together and double this period if each has to be operated separately.

The width of the entrances is important as a wide entrance enables rapid movement of passengers into or out of the car but it also results in longer door operating times. Entrances are usually 3 ft. 6 in. to 4 ft. 6 in. wide.

**Time for Passengers to Enter the Car.** This depends upon the number of persons entering, the width of the entrance, to some extent on the business of the occupants of the building, and whether or not an attendant is employed. The loading time

is shortened if the entrance is wide and also if a trained attendant drives the car instead of the control being automatic. At the ground floor the entrance should be as large as practicable to enable two or more passengers to enter or leave abreast.

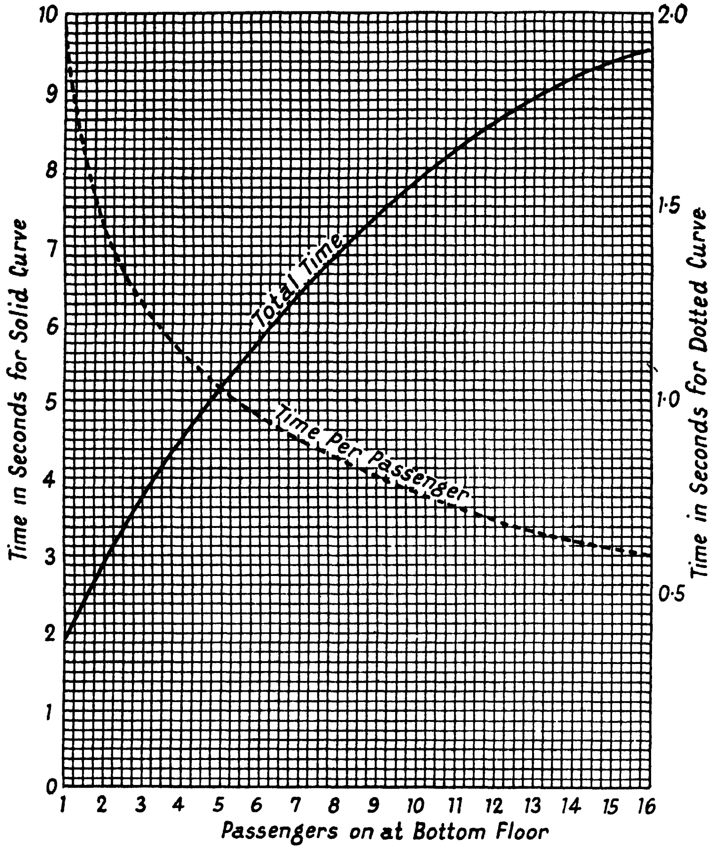



FIG. 3. PASSENGER LOADING TIME DURING PEAK ARRIVAL PERIOD IN OFFICE BUILDING

At the upper floors, however, the need for wide entrances is not so great, whilst any advantage that they will give by enabling rapid movement of passengers is offset by the time lost in door operation. The time required for passengers to

enter the car at the upper floors depends also on the number of passengers already in the car.

When loading the car at the ground floor the average time required for each passenger will vary with the number of passengers entering the car. If the car is partially loaded with, say, 4 or 5 persons, the average time per person will be about one second, but if the number of passengers comprise a full load of, say, 15 persons, the average time for each to enter may be about three-quarters of a second. In this case the earlier passengers instinctively move quicker if there are people behind whilst the later ones may, in turn, be urged by those who have to wait for the next trip. In filling the car an average time of one second for each passenger is reasonable for estimating, but a good attendant will improve on this time. A typical relation between the loading time and the number of passengers in an efficient attendant controlled lift service is shown in Fig. 3, in which the contract load is 15 persons and the lift entrances are 4 ft. 6 in. wide. A lift of this size would not normally be operated on automatic control by the passengers but if this were done it is likely that the time required would be at least double those indicated by the graph.

Although it is unusual to estimate for passengers entering the car at the upper floors during the peak period any such passengers would require rather longer time than that needed by one person entering at the ground floor. If a half filled car with 7 passengers stops at an upper floor to take on another 4 persons, these will probably require $1\frac{1}{2}$ seconds each as those already in the car will have to move inwards to make room for them. An average of $1\frac{1}{2}$ seconds for each of these passengers is reasonable for estimating.

**Time for Passengers to Leave the Car.** During the peak period passengers will leave the car at several of the upper floors and the time required to empty the car at the various landings will depend upon the number of passengers entering at the ground floor, and the number of stops made. At any particular floor the average time for a passenger to leave will be greater than that for entering as several of the passengers may have to move aside to enable him to leave. The time for three passengers to leave a full car would be about 6 seconds, but if these three were the last to leave they would probably

do so in half this time. The average time per passenger to empty a full car at one landing would be about $\frac{3}{4}$ second. Typical times required for passengers to leave a 15-person car stopping at various numbers of floors are shown in Fig. 4. These graphs relate to an efficient attendant controlled installation, but the times will be greater if the car is operated on automatic control.

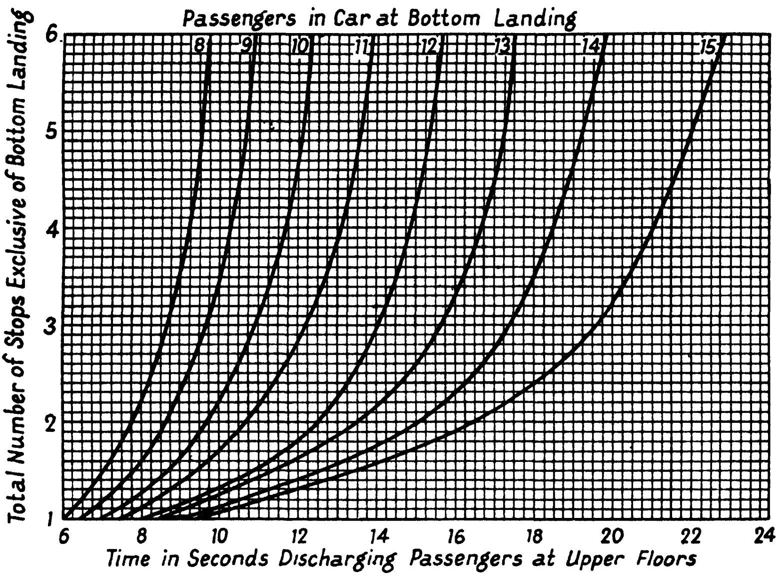



FIG. 4. PASSENGERS' UNLOADING TIME DURING PEAK ARRIVAL PERIOD IN OFFICE BUILDING

**Push Button or Car Switch Operation.** If automatic control is employed in which the car is operated by push buttons, some time will be required for the selection and operation of the appropriate buttons after the doors have closed. An average of two seconds is reasonable for this purpose. In modern lifts, however, the operation of the car switch usually closes the doors and then automatically starts the car so that no time is wasted. If the car switch has to be operated independently of the doors an additional average time of one second should be allowed for this purpose.

**Car Speeds.** Before consideration can be given to the travelling time between floors, a suitable car speed must be chosen. This depends largely on the height of the building, and if of 4 to 6 storeys a contract speed of 200 ft. per minute is quite common. For 6 to 8 storeys this can usually be increased with advantage to 300 ft. per minute. If the building has more than 8 storeys a speed of 400 ft. per minute or perhaps even as high as 600 ft. per minute should be considered.

For a speed of 200 ft. per minute the drive will usually be a two-speed squirrel-cage induction motor, or a tandem motor, the induction motor being employed for light duty where the number of starts per hour does not exceed about 100. For a heavy duty of about 200 starts per hour at this speed, a geared variable voltage drive or a ventilated tandem motor should be considered. At a speed of 300 ft. per minute the drive will invariably be geared variable voltage and for speeds of 400 ft. per minute and above, will be gearless variable voltage.

**Travelling Time.** The time to travel between successive stops is composed of periods of acceleration, running at contract speed and retardation. Rates of acceleration depend upon the type of motor used and may be as low as 1 ft. per second per second with a slow speed geared lift or as high as 6 ft. per second per second with gearless variable voltage control. In practice the higher rates are usually associated with high contract speeds. So far as the passenger is concerned there is no limit to the speed at which the car may travel as a velocity of 100 ft. per minute is the same as 1 000 ft. per minute to a passenger travelling in an enclosed lift car. There is, however, the effect of rapidly varying air pressures on the human system and particularly on persons with weak hearts. It is not yet clearly established how fast a man can be dropped through a given change of air pressure without causing serious discomfort or harm. Apart from this aspect the limit is not in velocity but the manner in which it is attained and how standstill is achieved.

The effect of acceleration and retardation on the human body is worthy of some consideration at this stage. Physical discomfort is caused by the movement of the internal organs and the accompanying pressure of these organs against other parts of the body. During acceleration downwards and retardation upwards the muscles of the viscera are partly relieved of

their load and the resulting reaction of these muscles tends to lift the visceral mass against the pleura which has not the resisting power of the bony pelvis and thus the stress is transmitted upwards to the lungs and heart. For this reason a sudden acceleration down or a sudden retardation up induces more discomfort than the reverse. A sudden increase in acceleration up or retardation down will affect the ankles of a stout person and the back of a thin person. These effects are worse the more abrupt the change in velocity, particularly if the muscles are not trained to quick response. Physical and mental preparedness will greatly minimize the effects. This may result in acceleration being much more uncomfortable than retardation, and explains why a lift car can be brought to rest much quicker than it can be accelerated without causing serious discomfort. To avoid discomfort the rate of change of acceleration or retardation, i.e. $\frac{d^3S}{dt^3}$ must be constant. Since therefore the acceleration must increase at a constant rate, the accelerating force must also increase at a constant rate if upward, and decrease at a constant rate if downward. Consequently during the accelerating period the acceleration and its applied force must gradually increase up to half the contract speed and then both must decrease at a constant rate from this point until maximum velocity has been reached, when the acceleration becomes zero. The retardation period is similar but is reversed. This is the ideal theoretical form of acceleration and retardation, but is rarely approached in practice and is, of course, very different from constant acceleration and retardation.

For the purpose of estimating the travelling time, distance/time curves for the accelerating periods for various car speeds are shown in Fig. 5, the points $X$ indicating the ends of the acceleration periods and the commencement of uniform contract speeds. The curves are drawn for constant acceleration which, except at low values, will result in uncomfortable travelling. This fact, however, does not materially affect the distance travelled during the accelerating period. The shorter time required to reach contract speed with a higher acceleration is indicated by the curves $C$ and $D$, which are for the same contract speed but $D$ has the higher acceleration. The various

distances travelled during acceleration show that if the higher speeds are employed for short journeys the car may not reach the contract speed before slowing commences.

The duration of the retardation period depends upon the method of slowing and on the adjustment of the brake but the rate should be as high as possible consistent with comfortable

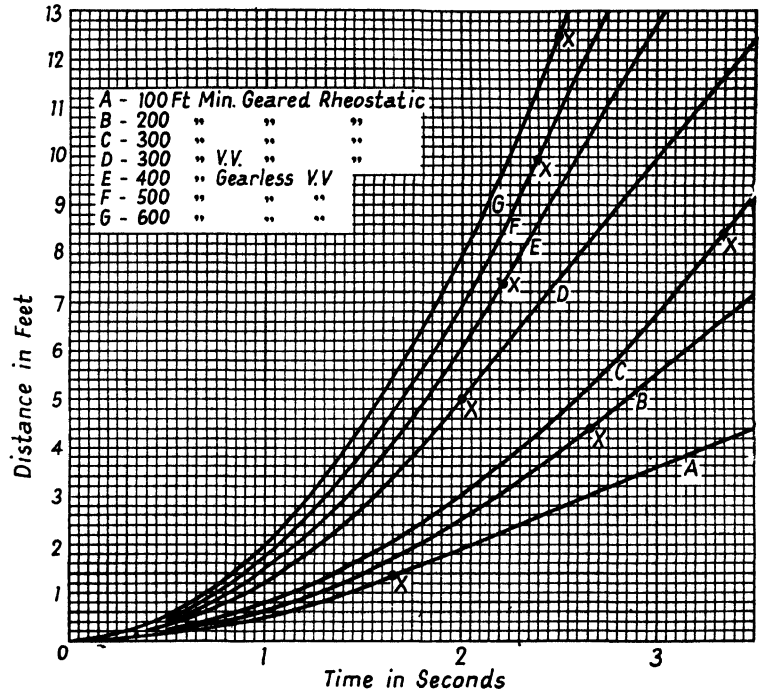



FIG. 5. TYPICAL ACCELERATION CURVES FOR VARIOUS LIFTS

travelling. For the purpose of estimating the travelling time it is usual to assume that the rates of acceleration and retardation are equal. Consequently the retardation curves will be similar to those for acceleration shown in Fig. 5 but will be reversed. Curves showing the total travelling times for the same speeds as in Fig. 5, when stops are made between floors 30 ft. apart, are shown in Fig. 6. The constant speed periods are between points $X$ and $Y$ and from curves similar to these

the total travelling time between stops may be estimated. The curves are drawn for values of accelerations and retardations likely to be obtained in practice with the contract speeds quoted. These represent average uniform values but instantaneous accelerations greater than these may be experienced depending upon the method of control employed.

It is possible to calculate the actual travelling time of a

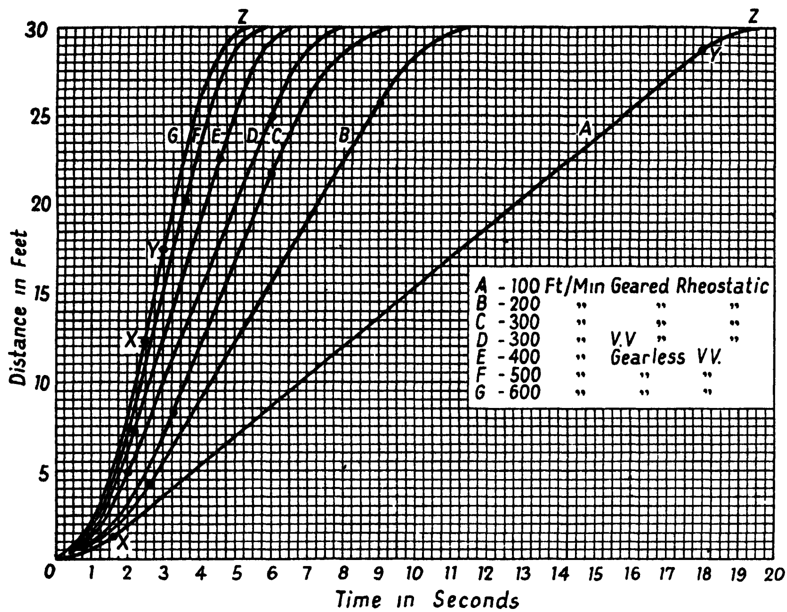



FIG. 6. TYPICAL TIME/DISTANCE CURVES FOR VARIOUS LIFTS

round trip during the busy period after the probable number of stops have been ascertained and the distance travelled during an acceleration or retardation period is known or can be estimated.

This may be done as follows—

Let $S$ = the number of stops made between the ground and the uppermost floor at which passengers are unloaded.

$D$ = the distance in feet between the ground and this top floor.

$V$ = the contract speed in feet per second.

$d$ = the distance in feet required for acceleration from rest to contract speed which is assumed to be equal to the retardation distance.

The average round trip during the morning busy period in an office building consists of loading at the ground floor, unloading during $S$ stops at the upper floors and a non-stop return to the ground floor.

The distance travelled on the upward journey during the acceleration and retardation period $= 2dS$ ft.

And the distance during the acceleration and retardation periods when returning to the ground floor $= 2d$ ft.

Therefore the total acceleration and retardation periods $= 2d(S+1)$ ft.

The total distance travelled at contract speed $= 2D - 2d(S+1)$ ft.

Therefore the total time during acceleration and retardation periods $= \dfrac{2d(S+1)}{\dfrac{V}{2}} = \dfrac{4d(S+1)}{V}$ sec.

This assumes that the average speed during these periods is half the contract speed.

Time for running at contract speed $= \dfrac{2D - 2d(S+1)}{V}$ sec.

Therefore, the total travelling time $= \dfrac{2}{V}(dS + D + d)$ sec.

This formula holds good only if the distance between stops is large enough to enable the car to reach the contract speed before slowing commences.

If the distance $d_1$ between any two stops is less than the distance needed to reach contract speed, the travelling time between these stops will be $2\sqrt{\dfrac{d_1}{f}}$ sec. where $f$ is the average acceleration. The total time must be modified accordingly.

**Miscellaneous Times.** If the lift is car switch controlled and automatic levelling is not incorporated, the accuracy of levelling is entirely dependent upon the skill of the operator. In these cases it is usual to allow an extra one second for each stop to cater for occasional inaccuracies in levelling which may necessitate "inching."

The lifts in a bank are sometimes dispatched automatically or automatic signals are sent to the operators to ensure that, as far as is practicable, the regular schedule is maintained. If this feature is not provided, an additional 10 per cent should be allowed on the R.T.T. to cover possible running off schedule.

**Typical Example of Lift Traffic Analysis.** After estimating or calculating values for the various factors affecting lift service as described above, consideration can be given to the possible number and types of lifts to meet the particular requirements. For the purpose of demonstrating the principles involved in the traffic analysis of a typical large office building the following example will be considered.

There are 8 floors above the ground or entrance level together with a sub-ground and basement and the occupants and rental value are such that a high grade of service is necessary. One main entrance in the centre of the frontage indicates that a bank of lifts is required. In estimating the probable number of stops during the busy period, traffic to the basement, sub-ground and 1st floors will be ignored. This will either be prohibited during these periods or the number of persons desiring service to these floors will be so small that it can be neglected at this stage. The busiest traffic period of the day in this building is considered to be during a particular half-hour in the morning when the building is being filled and it is estimated that 75 per cent of the normal population on the second floor and above will require lift service during this period. Hence the actual number of people to be taken to the upper floors can be assessed from data on the population of each floor. The number travelling to each of these floors is found to be sufficient to warrant making service available to all these floors during the busy half-hour. The total number requiring such service is 662 made up as shown in the table below—

| Floor | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| No. of persons requiring service | 36 | 93 | 160 | 85 | 120 | 105 | 63 |

The maximum capacity of the car will be assumed to be 10 persons and it is now possible to calculate the probable number of stops in unloading 10 persons during the busy period.

The distance between the ground and 8th floor is 110 ft. and this justifies considering speeds of 300 and 400 ft. per minute. To provide a high grade of service the door operating time must be small and therefore power operated doors should be provided, and, in addition, the lifts should be attendant operated. The round trip time can now be considered and will comprise door opening and closing, passengers entering and leaving, travelling time and any extras. During each round trip 10 passengers

LIFT TRAFFIC ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| Contract Load (persons) | 10 | 15 | 20 | 10 | 15 | 20 |
| Contract Speed (ft./min.) | 300 | 300 | 300 | 400 | 400 | 400 |
| Probable No. of Stops per Trip | 5·21 | 5·97 | 6·37 | 5·21 | 5·97 | 6·37 |
| Door Operating Time (seconds) | 21 | 24 | 27 | 21 | 24 | 27 |
| Passengers Entering and Leaving (seconds) | 20 | 33 | 47 | 20 | 33 | 47 |
| Travelling Time (seconds) | 56 | 58 | 59 | 46 | 48 | 49 |
| Total Time (seconds) | 97 | 115 | 133 | 87 | 105 | 123 |
| 10 per cent for off Schedule | 10 | 12 | 13 | 9 | 10 | 12 |
| R.T.T. (seconds) | 107 | 127 | 146 | 96 | 115 | 135 |
| No. of Lifts | 4 | 3 | 3 | 4 | 3 | 3 |
| Persons Carried in 30 minutes | 672 | 640 | 740 | 750 | 705 | 800 |
| Waiting Interval (seconds) | 27 | 42 | 49 | 24 | 38 | 45 |
| $\frac{\text{W.I.}}{4}(2 + N)$ | 40 | 53 | 61 | 36 | 48 | 57 |
| Grade of Service | Excellent | Good | Fair | Excellent | Good | Fair |

will be carried and after determining the R.T.T. as already outlined it is possible to estimate the number of 10-person lifts required to deal with 662 persons in 30 minutes. The grade of the resulting service, i.e. $\frac{\text{W.I.}}{4}(2 + N)$, can also be assessed. It is necessary to consider other possible combinations of lift sizes and speed, and the table above shows the traffic details for this building with cars of 10, 15, and 20 passengers capacity and contract speeds of 300 and 400 ft. per minute all calculated as described above.

A selection must now be made from these possible installations depending upon the quality of service required and the price that the building owners are prepared to pay for lift

service. It will be seen in this case that four lifts of 10 persons capacity each at 300 ft. per minute will handle the traffic, that W.I. is low and the grade of service excellent. Three 15-person lifts at 300 ft. per minute will deal with the traffic sufficiently closely for practical purposes, but the waiting interval is rather high and the grade of service inferior. The improvement

FIG. 7. THREE GEARLESS MOTORS
(*Express Lift Co. Ltd*)

in service by running these three 15-passenger lifts at 400 ft. per minute is not sufficient in this case to justify the extra cost. The four 10-passenger lifts at 400 ft. per minute are unnecessarily extravagant, whilst both the 20-passenger installations are too large and the grade of service not good enough for a high-class building. The best arrangement is therefore four 10-passenger lifts at 300 ft. per minute, and the next, and a cheaper one, is three 15-passenger lifts at 300 ft. per minute. For a building of this type, lifts at 500 ft. per minute might also be included in the analysis. In a similar manner, possible arrangements for any particular building can be studied.

The traffic in buildings used for other purposes might not

have such pronounced short period peaks as an office building. For example, in a large departmental store the peak load is spread over a much longer period and furthermore is two-way traffic. In considering the design of lift installations some important facts are that high speeds are uneconomical if there is a great deal of floor to floor traffic and that greater improvements in the grade of service can be made by speeding up door

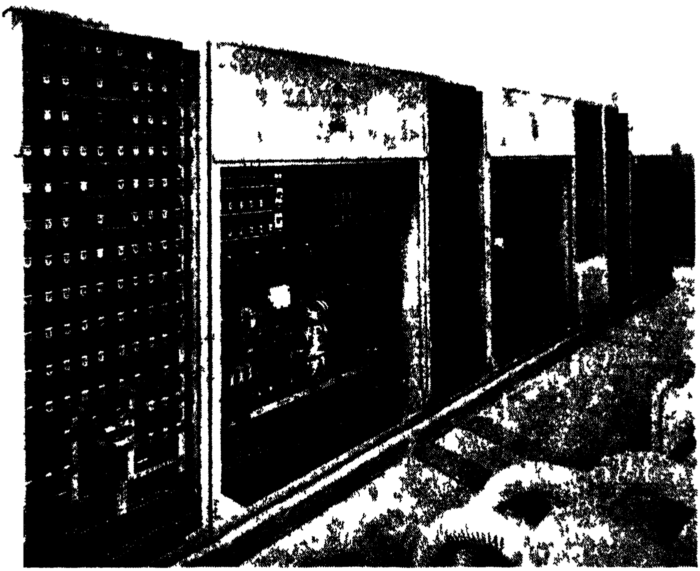


FIG 8 INTERCONNECTED CONTROLLERS FOR MOTORS IN FIG 7
(*Express Lift Co Ltd*)

operation or time for loading and unloading passengers than by increasing the contract speed. Control by car switch is usually more efficient than by push buttons operated by passengers and the latter should not generally be used for passenger lifts larger than 10-persons capacity as it is uneconomical to allow a large lift to answer single calls. If several lifts are required to handle heavy traffic from a number of landings it is advisable to install signal control in which the attendant only controls starting and the lift stops automatically at each landing where a call has been registered. Dual control should be fitted on

one or more lifts in a bank if periods of light traffic such as at night are anticipated when these lifts can be operated on automatic control and the others shut down. It should be borne in mind, too, that in such circumstances automatic power operated doors or at least door closers (although these have the disadvantage of being more difficult to open) are a great advantage in ensuring that a lift is not put out of service by a passenger leaving and failing to close the door. Figs. 7 and 8 show the gearless motors and controllers respectively for the lifts in Figs. 1 and 2.

## LIFTS FOR SPECIAL PURPOSES

Many lifts are installed in buildings other than office blocks and because of the rather unusual nature of the traffic, sometimes demand special consideration. The main features of some of these types of lift are mentioned below.

(*a*) **Lifts for Workers' Flats.** Small capacity lifts at a low speed are required for this purpose, and the usual sizes are four, six or eight passengers capacity with a contract speed of 100 or 150 ft. per minute. The duty is generally not heavy and a single speed induction motor is satisfactory. Delivery of tradesmen's goods is a regular occurrence, and small articles of furniture and perambulators frequently have to be accommodated in the car. This is often constructed of steel or hardwood and sometimes faced with formica, which is durable, not easily defaced and obtainable in a variety of colours and patterns. Corners and angles should be kept to a minimum to facilitate cleaning. Another very satisfactory car lining for this purpose is made of sheets of an alloy of manganese and aluminium. The surface of this material, fluted or ribbed vertically, requires little maintenance, and disfiguration by scratching or writing is not easy. This material is also used for the door surfaces and the landing architraves. To reduce malicious damage to a minimum the fixing screws for any equipment should be inaccessible from the landings or the car.

To give a maximum degree of safety, solid doors are provided for the landing and car entrances and are usually power operated and fire resisting. Door closing is sometimes effected by a simple door closer of the falling weight type instead of power operation. Another safety feature in common use is the

fitting of a concealed switch in the leading edge of the landing and car doors which, if operated by the door meeting an obstruction, automatically reverses the door operator motor and opens the door. The door bottom tracks are of the self-cleaning type to minimize maintenance and possible failure of the door operator. The running clearances between the car and landing thresholds is only about half an inch to avoid the risk of trapping the heels of ladies' shoes. To minimize operation by children the push buttons are usually fitted at a height of about 5 ft. 6 in., and if a large number of floors is served they may be mounted horizontally instead of vertically so as not to extend more than six feet above the floor. In some cases Yale locks are fitted instead of push buttons, the tenants being supplied with keys.

Automatic control is provided, with a single call button at each landing and a full set in the car. Another control feature is that the car and landing doors are normally closed when the lift is stationary at a landing, and this assists in keeping the inside of the car clean. A "Door Open" button is also fitted in the car. With solid doors the usual emergency stop button fitted in the car is sometimes omitted as being unnecessary in these circumstances and also to eliminate the possibility of the car stopping in such a position that, although the door electric interlock is broken, the mechanical lock remains in the locked position. In this event the door motor would operate against its slipping clutch without moving the door and so possibly damage the mechanism. When this emergency stop button is not fitted, however, it is advisable to provide a mechanical lock on the car door so that it cannot be opened forcibly to stop the car.

For this type of lift it is necessary to pay attention to features that will ensure silent operation, as the lifts may be in service for twenty-four hours a day. Hence the lift well is totally enclosed and arranged so that the minimum of noise and vibration is transmitted to other parts of the building. The use of slowing and stopping switches in the well is eliminated, and these functions are performed by a selector in the machine room, driven from the car, or by inductors. The winding machine is insulated from the building by pads of compressed cork or rubber. A small belt-driven machine with a single

speed induction motor, suitable for this service, is shown in Fig. 9. The life of this vee belt drive is quite satisfactory, and it has some advantages over the usual direct couple motor drive. It provides a small and compact winding machine and

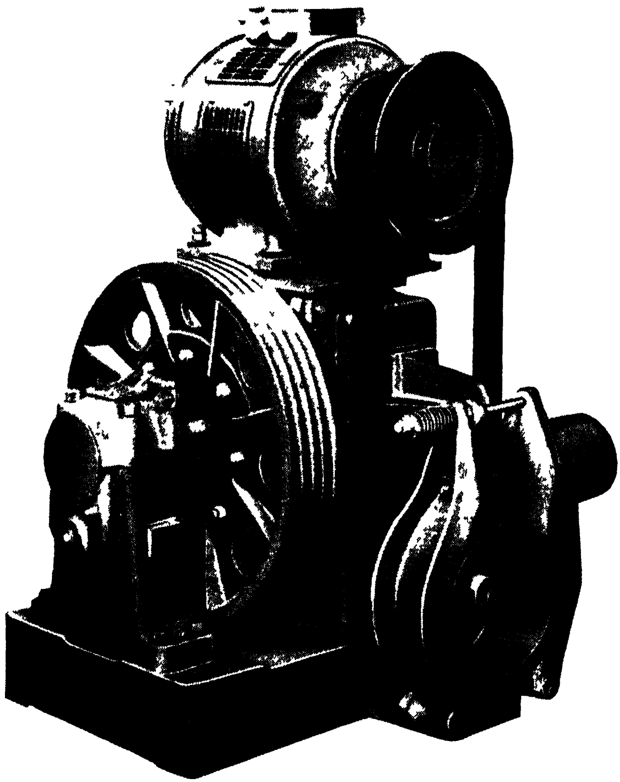


FIG. 9. SMALL WINDING MACHINE FOR SINGLE SPEED LIFT
(*Express Lift Co. Ltd*)

eliminates the necessity to align carefully and correctly the motor sheave and the worm shaft, which is a highly-skilled operation. Further, the motor can readily be removed for repair or replacement.

As an additional safeguard the control circuit voltage is kept as low as practicable and is usually 100 volts d.c. Thus, in the

event of malicious damage to any control wiring, the risk of a serious electric shock is diminished.

(*b*) **Hospital Bed Lifts.** These lifts have deep cars to accommodate stretcher trolleys and consequently the floor area is

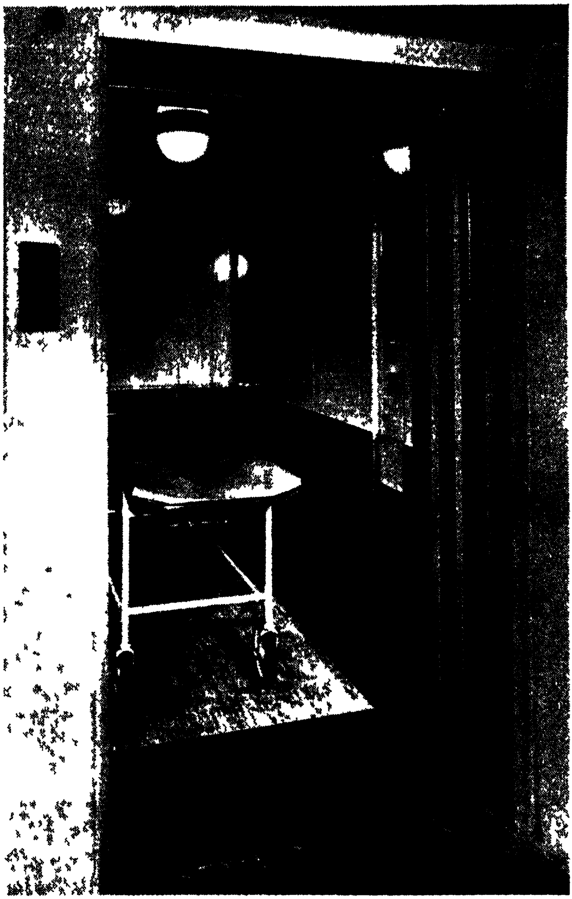


FIG. 10. BED LIFT WITH POWER OPERATED DOORS
(*Express Lift Co Ltd*)

large. From the safety aspect it is desirable to rate the winding machine as if the lift were a normal passenger lift. Although for most of the time the machine is thus over-rated there may

be occasions, e.g. visiting days, when such a lift will be required to carry a full load of passengers. Typical car sizes are 5 ft. 4 in. × 8 ft. and 5 ft. 8 in. × 8 ft. 4 in. rated at 3 500 lb. (twenty-three persons) and 4 000 lb. (twenty-seven persons), respectively. As a wide entrance is required, two-speed side opening doors are provided. A contract speed of 100 ft. per minute satisfies most requirements although in some cases 200 ft. per minute is adopted. Accurate floor levelling is essential and hence the levelling speed should not exceed 30 ft. per minute whilst a corrective levelling system is preferable. The whole installation should be as quiet as possible, winding machine, door and well noises must be small, and it is sometimes better from this aspect to install the winding machine in the basement. Cleanliness is important and it is therefore desirable that the well should be totally enclosed and solid doors fitted. Adequate space is required at landings to permit of easy manoeuvring of bed trolleys. A bed lift is shown in Fig. 10.

(*c*) **Lifts in Ships.** As these are subjected to the rolling and pitching of the ship, special treatment must be given to many items of the control and to other equipment. It is desirable that the centre of gravity of the ship should be as low as possible, and therefore the ship designer prefers the lift machine to be installed at the bottom of the well. On the other hand, the lift engineer is well aware of the advantages of having the machine above the well, this feature being referred to in a later chapter. Considerable discussion is necessary between both parties before one or other of these positions is finally agreed. As a compromise the machine room is sometimes located at an intermediate position.

The counterweight does not travel down to solid ground as in a shore installation, and it is therefore necessary to fit safety gear to the counterweight as well as the car.

The travelling cables need special protection to prevent their swaying with the ship's motion and fouling projections in the lift well. It is usual to enclose these in canvas sheaths and house them in a special flush trunk inside the steel well structure. Consequently the well clearances required are somewhat greater than those needed for land lifts.

It is necessary to ensure that the movement of the doors is not erratic because of the ship's rolling, and this is achieved

by using power-operated centre-opening doors, the two panels moving in opposite directions and being self-balancing.

The electricity supply in ships is usually d.c., which is not common to-day in land installations, and the equipment is therefore somewhat different from the lift manufacturer's standard equipment.

The speed of ships' lifts is usually either 100 or 200 ft. per

FIG. 11. PASSENGER LIFT ON T.S.S. "OCEAN MONARCH"
(*Express Lift Co. Ltd.*)

minute, and the capacity of the passenger lifts eight or ten persons. A ship's passenger lift is shown in Fig. 11.

(*d*) **Private Residence Lifts.** In large private residences a lift similar in most respects to that provided in the smaller office buildings is usually suitable. Special landing entrance, door and car finishes, however, are often required. The Shepard Home Lift shown in Fig. 12 is a small 350 lb. capacity electric lift of unique design manufactured by Messrs. Hammond & Champness and is of particular value for invalids

and old persons. The outside dimensions of the car are 3 ft. by 3 ft., and it will accommodate a wheel chair. For single phase a.c. supply a ½ horse-power capacitor motor drives the

FIG. 12 SHEPARD HOME LIFT
(*Hammond & Champness*)

car through a worm gear, electromagnetic brake and two simplex roller chains operating over sprocket wheels at a contract speed of 15 ft. per minute. Because of the small power available, frictional resistances are kept to a minimum and

## DETAILS OF MODERN LIFT INSTALLATIONS (EXPRESS LIFT CO. LTD.)

| Type of Lift | Type of Building | Contract Load (lb.) | Contract Speed (ft. per min.) | Total Travel ft. | Total Travel in. | No. of Floors | Motor and Drive | Control System, etc. |
|---|---|---|---|---|---|---|---|---|
| PASSENGER | OFFICES | 3 500 | 500 | 78 | 4 | 8 | Gearless V.V. | 2 banks of 4 cars, ET control |
| | | 2 500 | 500 | 103 | 0 | 10 | Gearless V.V. | 2 banks of 4 cars, ET control |
| | | 1 500 | 400 | 79 | 9 | 8 | Gearless V.V. | 2 cars DSC 2 control |
| | | 2 500 | 300 | 92 | 8 | 8 | Geared V.V. | 3 cars DSC 2 control |
| | | 1 500 | 200 | 48 | 3 | 5 | Geared Tandem | 2 cars DSC 2 control |
| | AIRPORT | 4 800 | 300 | 66 | 0 | 6 | Gearless V.V. | 2 pairs of cars DSC 2 control |
| | FLATS | 1 200 | 100 | 87 | 6 | 11 | Geared Single Speed | Twin lift with collector control serving alternate floors |
| | | 1 200 | 100 | 28 | 9 | 4 | Geared Single Speed | Push button or automatic control |
| | HOTELS | 2 000 | 500 | 110 | 3 | 11 | Gearless V.V. | 3 cars DSC 3 control |
| | STORES | 4 500 | 350 | 110 | 0 | 9 | Gearless V.V. | 6 cars with car switch control |
| | | 3 500 | 350 | 95 | 0 | 8 | Gearless V.V. | 4 cars with car switch control |
| | L.C.C TUNNELS | 9 000 | 150 | 50 | 3 | 2 | Geared V.V. | Push button or automatic |
| | | 6 000 | 150 | 63 | 2 | 2 | Geared V.V. | Push button or automatic |
| GOODS | FACTORIES | 3 360 | 200 | 44 | 0 | 4 | Geared Trulevel | Car switch self-levelling |
| | | 4 480 | 150 | 40 | 3 | 3 | Geared Trulevel | Push button or automatic |
| | | 6 720 | 100 | 26 | 9 | 3 | Geared Trulevel | Push button or automatic |

All passenger lifts in above table except those for L.C.C. Tunnels have power-operated sliding doors on car and landing.
All goods lifts in above table have power-operated rising car gate and power-operated bi-parting doors on landings.
ET control = Express Traffic control which is basically a Signal Collector control with the addition of a supervising system for catering for varying traffic conditions.
All cars can be operated with or without attendant.
DSC 2 and DSC 3 control = Directional Signal Collector control with intercommunication for 2 or 3 cars.
All cars can be operated with or without attendant.

ball bearings used wherever possible. The car shoes consist of four roller-bearing bakelite wheels which travel within the two dry special shaped steel channel guides. The small winding machine, which is 12 in. in height, is housed behind the transome panel above the lift entrance and is provided with a handle for winding in an emergency. Serrated cam safety gear is fitted to the car and operates if either suspending chain breaks. A counterweight is not provided, the free ends of the chains passing over guide pulleys and thence to light supports on the winding machine framework. Control is automatic with an "Up" and a "Down" button at each landing and in the car. The car entrance is protected by a collapsible gate which, being constructed of polished hardwood pickets and plastic lattice bars, is very easy to operate. The enclosure on the upper floor is protected by a solid door with an electro-magnetic interlock. This lift is a self-contained unit, the guides are fitted to a wall and no enclosure is required on the lower floor. If the car meets an obstruction during descent, the false movable underfloor is compressed and thus operates two switches which cut off the power supply and automatically stop the car.

## GOODS LIFTS

In many buildings it is necessary to install one or more goods lifts, these being designed primarily for the transport of goods, but occasionally to carry passengers. The design of a goods lift is similar in principle to that of a passenger lift, the main differences being that the car is of rougher construction, the entrances wider and the contract speed rarely exceeds 200 ft. per min. Accurate levelling, however, may be essential to facilitate the loading and unloading of trolleys filled with fragile goods, and in these cases one of the available schemes of corrective levelling is often incorporated. The service is usually intermittent, and the control is therefore either automatic or semi-automatic.

In determining the minimum contract load for a goods lift, careful consideration must be given to the type and size of load to be carried and the method of loading and unloading. For general goods which are distributed over the car floor, the contract load should be four times the weight of the heaviest

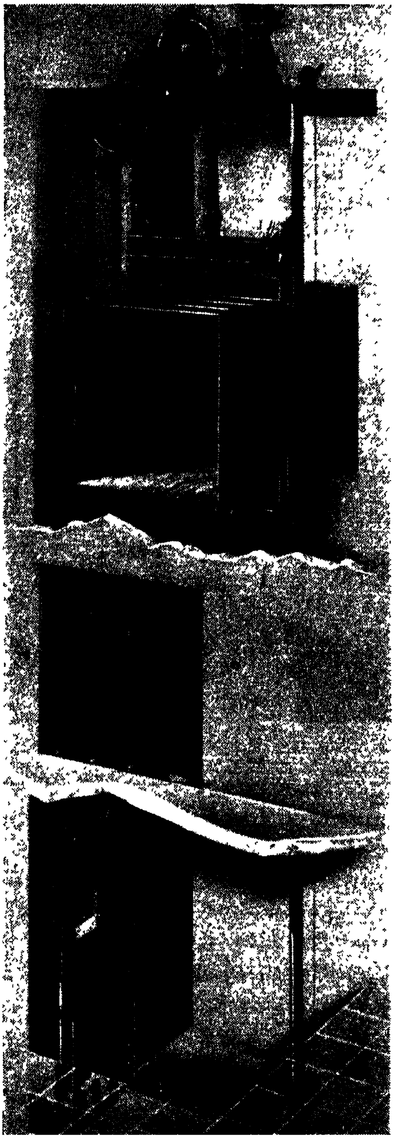


Fig. 13. Goods Lift with Bi-parting Doors
(*Waygood-Otis, Ltd.*)

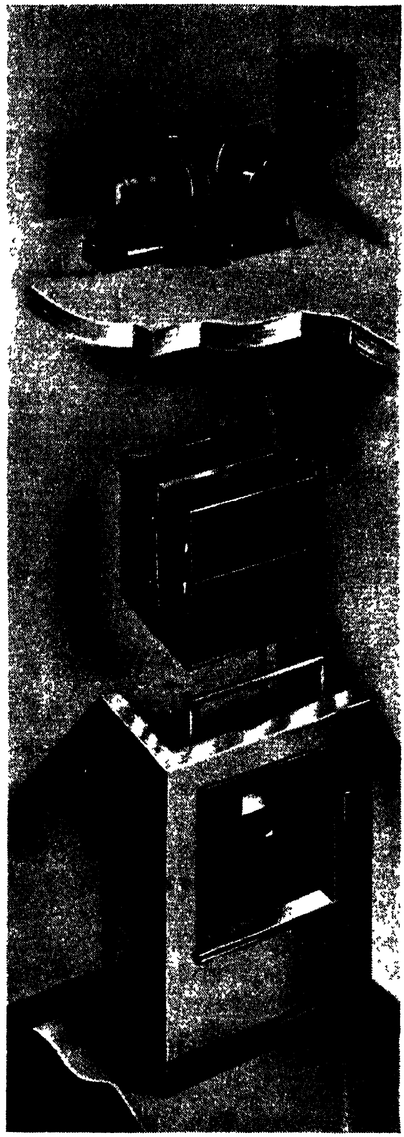


Fig. 14.
Typical Service Lift
(*Waygood-Otis, Ltd.*)

single item or 70 lb. per square foot of car floor area, whichever is the greater.

If the goods are in a power-operated truck and the truck, together with its load, must be carried in the lift, the minimum contract load must be the total weight of the truck and its maximum load. If the goods lift is to be used to transport motor vehicles, the contract load must be equal to the weight of the heaviest vehicles to be carried or 35 lb. per square foot of

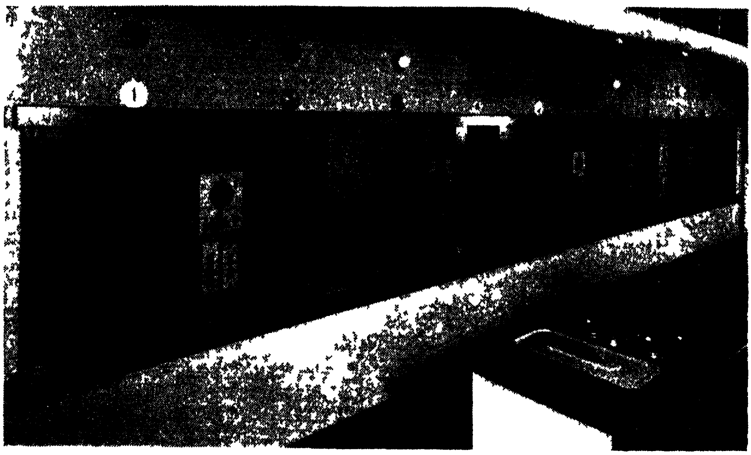


FIG. 15. A BANK OF SERVICE LIFTS
(*Marryat & Scott*)

car floor area, whichever is the greater. Special consideration must also be given to the car guides and their fixing because of the side loads that may be imposed when a heavy truck enters or leaves the car. Heavy goods loads demand well-designed brakes and adequate rope traction to avoid slipping in the sheave grooves. A typical goods lift is shown in Fig. 13. This is fitted with bi-parting landing doors which is a feature of large modern goods lifts.

**SERVICE LIFTS**

A service lift is one which is designed and constructed so that it is possible for goods only to be carried, and the factor of human safety does not therefore enter so largely into the design of these lifts. Usually the floor area does not exceed 9 sq. ft.,

and the car height does not exceed 4 ft. The capacity does not exceed 5 cwt. Fig. 14 shows a typical service lift car and winding machine. The type is chiefly used in hotels and restaurants for service from the kitchens to the dining-rooms, in banks for the transport of bullion, and in libraries for transport of books. The general principles governing the design are similar to those for a goods lift, but the machine and car are much smaller in size and safety gear is generally omitted, although buffers are fitted under the car and counterweight. The speed of travel is invariably between 50 and 150 ft. per min., whilst the control is either automatic or semi-automatic. Fig. 15 shows a bank of automatic service lifts in a large public restaurant. They can be called or sent to all floors, and a loudspeaker-microphone telephone system allows conversation between floors. The cars are lined with Formica and are fitted with rise and fall hatches. The fittings are of stainless steel.

The table on page 33 gives details of typical modern British lifts.

# CHAPTER II

## ACCOMMODATION

**Well.** In most buildings the lift well is placed in or adjacent to the main staircase, but, whilst in some buildings these positions have advantages, lift engineers nowadays frequently avoid the stairs when designing the well and, in fact, in America some building authorities prohibit the erection of the well in the stairway, the latter being regarded solely as a means of exit during emergency. Stairway wells often present difficulty in regard to guide fixings. The advantages of placing the well in a separate portion of the building are that there is not the same tendency for dirt to accumulate, the well can be totally enclosed by walls which will support the guides rigidly, and no special methods of guarding and screening are necessary. A typical guarded stairway well with car lined with Formica is shown in Fig. 16. Furthermore, most stairway wells are unsightly, and so the architect who avoids using them for his lifts is better able to contrive a more pleasing appearance for his lift entrances. An example of a totally enclosed well with an effective entrance is shown in Fig. 17. This is a bank of three passenger lifts in one well with one overhead machine room. The control is triplex collective variable voltage, geared motor with load of 2 000 lb and speed 300 ft. per min. The main point for consideration is that the lift should afford a quick and easy means of access to an exit from the upper floors.

The area of the well is governed by the size and number of the cars, and by the disposition of the car and landing entrances; these entrances also determine the necessary clearances for the car and counterweight. Various arrangements of openings met with in practice, with suitable average clearances for car and counterweight, are shown in Fig. 18, although the clearances will depend upon the car size and the type and method of fixing of the guides. Sufficient pit depth must be allowed to enable the car to come to rest without excessive buffer shock after operating the final stopping switch in the event of the normal stopping switch failing to operate. The depth required depends

upon the contract speed and the type of buffer employed and is usually between 3 ft. and 5 ft. with spring buffers and between 5 ft. and 10 ft. with oil buffers and speeds up to 600 ft. per min. The minimum overhead clearance which should be given is also

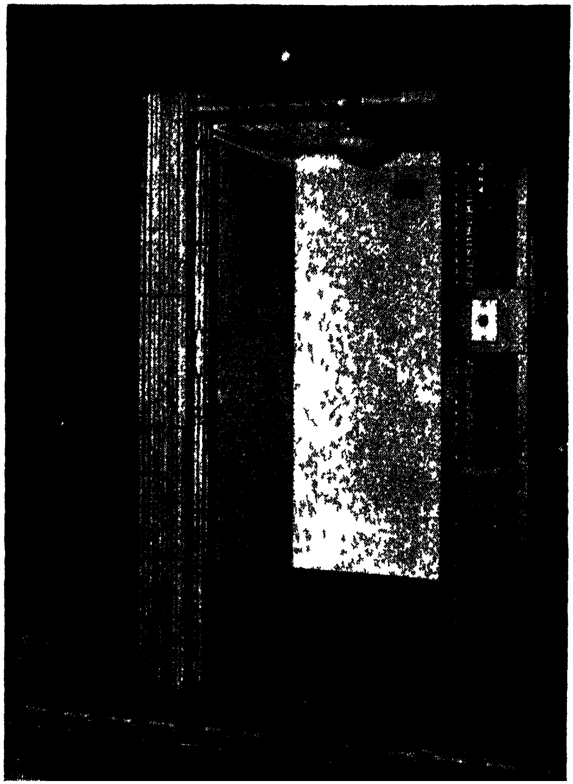


FIG 16 STAIRCASE LIFT
*(Marryat & Scott)*

a function of the contract speed. These clearances are given in Chapter XII. Provision must be made in the pit bottom for the accommodation of buffers, usually two for the car and two for the counterweight, if spring buffers, and for the fixing of the guide ends. Counterweight buffers, whilst not installed on all lifts, are invariably provided when the well does not extend to

the basement. In these circumstances a special framing is erected for the buffers, and this must be capable of supporting the weights of the car and counterweight together with a possible impact strain. The lift machine is generally either in the basement or at the top of the well, but in both cases a suitable structure is required at the top of the well. In the former case the top joists must be capable of supporting the diverting pulleys and their resultant loads, whilst in the latter case the

FIG 17. THREE PASSENGER LIFT ENTRANCES
(*Marryat & Scott*)

top structure is subjected to the weights of the machine, car, counterweight, and control gear. With the basement position, the machine should never be immediately under the well, and it is therefore necessary to provide joists for supporting the bottom pulleys which lead the ropes into the well. It is frequently possible to fix the main supporting joists to the building framework, but in some cases this is impracticable and it then becomes necessary to erect an independent steel structure from the basement and so relieve the building fabric of all lift loads. The well is usually of brick construction faced either with plaster or some form of ornamental glazed brick, except when a steel structure has to be erected.

No equipment, except that forming part of the lift or necessary for its maintenance, should be installed in the well. The inside surface of the well should, as far as practicable, form a continuous flush surface, but if projections which are opposite a car entrance and extending inwards from the general well

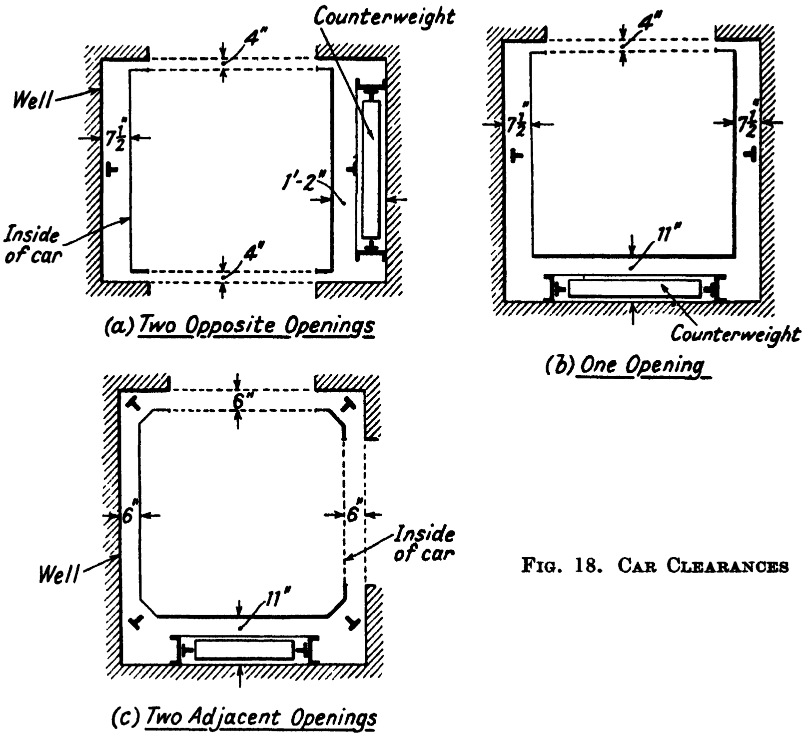



Fig. 18. Car Clearances

surface cannot be rendered flush, they should be levelled on the underside.

Well openings all on one side should be arranged if possible, as this permits of a simple guide arrangement and cheaper car construction. Exits on opposite sides can be arranged without difficulty, but openings on adjacent sides involve guiding the car at its corners.

**Machine Room.** The overhead location of the lift machine

shows a saving in first cost and has several engineering advantages over the basement or any intermediate position. The machine room should therefore, whenever possible, be situated directly over the well and should have sufficient windows to afford good natural lighting and ventilation. The former is necessary for efficient maintenance, and adequate artificial lighting supplemented by hand lamp points should be provided

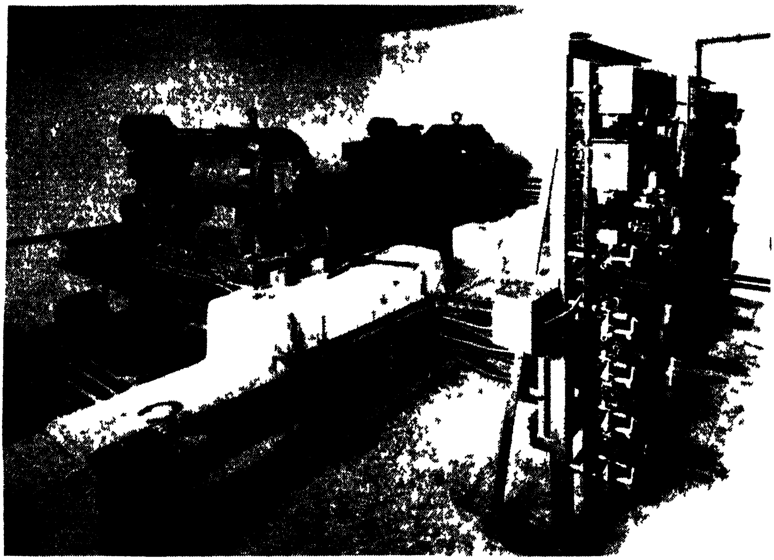


FIG. 19 MACHINE ROOM FOR TWO PASSENGER LIFTS
*(Marryat & Scott)*

for carrying out any work necessary during hours of darkness. Efficient ventilation is provided mainly to reduce the temperature and resistance of the motor windings, and thereby increase the electrical efficiency of the plant. An overhead machine room for two passenger lifts with two-speed a.c. motors is shown in Fig. 19. In large machine rooms where a number of lift machines is installed it is sometimes the practice to install a Plenum ventilating plant. The incoming air is drawn through filters and thence by ductwork to the generators and motors, a separate exhaust system being provided. The clear room height should not be less than 7 ft. The entrance

door should preferably open outwards, and when it is essential to locate the machine below, access doors must be provided at the top of the well to enable the necessary periodical attention to be given to the overhead pulleys. The machine room should be restricted to the housing of lift equipment. It is advisable that the walls, floor and ceiling of the machine room be properly finished to reduce to a minimum dust emanating from brick or concrete surfaces. This can have a serious effect on controller contacts, and to prevent dust settling on the oiled guides the well should be properly surfaced.

The area of the room depends upon the lay-out and type of the lift equipment, the size being governed by the car capacity and speed. Ample space must be provided to facilitate maintenance, and means, e.g. a trap door in the floor, whereby any items of equipment may be removed for repair or replacement. In the lay-out care must be taken to ensure that the controller position conforms to the Home Office Regulations, which demand that there should be a clear width, measured from the bare conductors, of not less than 3 ft. on all sides. When the controller is fixed near a wall the 3 ft. clearance must be provided between the controller and the wall, unless the connexions and all parts requiring attention when the controller is working, are placed on the front of the panel. The floor should be capable of supporting the heaviest lift unit and is usually designed to withstand a concentrated load of 300 lb. on any 4 sq. in. of the floor. This does not require that it shall be capable of supporting 300 lb. on every 4 sq. in. of its surface simultaneously. The sizes of well-designed machine rooms for various capacity single lifts will, in practice, be found to be approximately those quoted in the tables on pp. 49–53, which also give information relating to other accommodation requirements.

The figures in the table for light traffic lifts relate to single speed lifts with the counterweight at the side of the car. They have single entrances with single sliding panel doors either hand- or power-operated.

The table on page 50 gives typical dimensions for geared lifts for general office type buildings. Each lift has a single entrance with two-panel power-operated doors, side opening or centre opening. The counterweight is opposite the landing entrances

and the machine room directly above the well. The total headroom is the distance from the top landing to the machine room ceiling, and the pit depth the distance from the bottom landing to the pit floor. Fig. 20 gives details of the layout of a typical lift for this type of duty and, it is also suitable for the

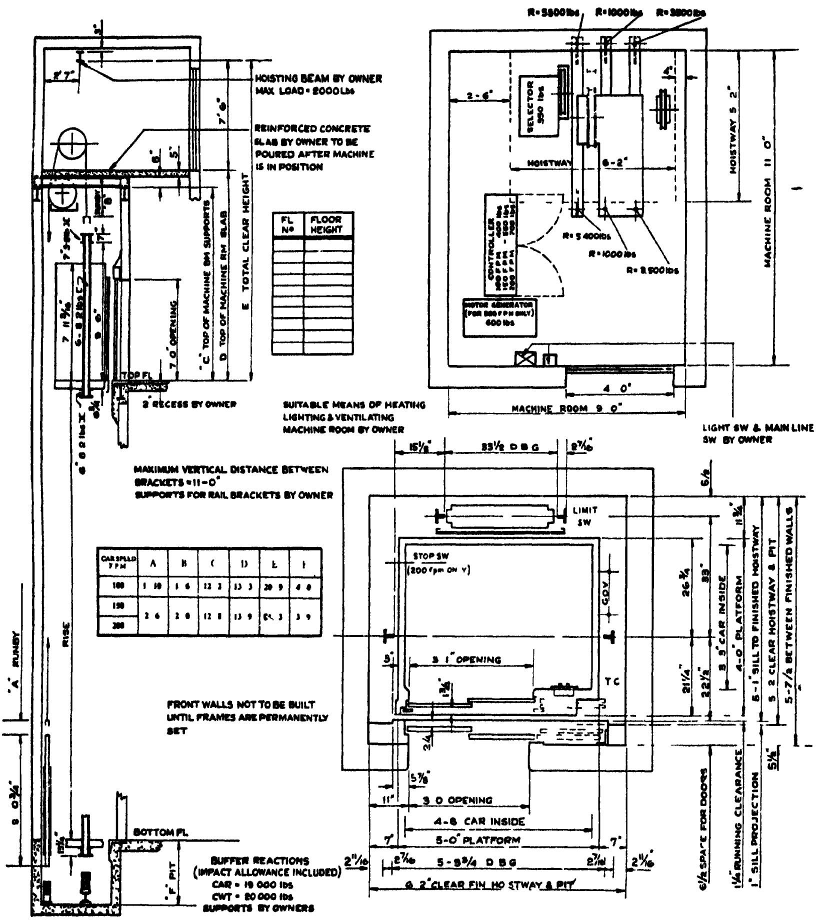


FIG. 20. TYPICAL GENERAL PURPOSE GEARED PASSENGER LIFT

(1 200 lb. at 100 ft. per min., 150 ft. per min. or 200 ft. per min.)

(*Waygood-Otis, Ltd.*)

light traffic duty referred to in the preceding paragraph, except that in this case the counterweight position and the doors are different from those mentioned above. Fig. 21 shows details of a larger lift with centre opening doors.

The figures in the table on page 51 for heavy traffic passenger

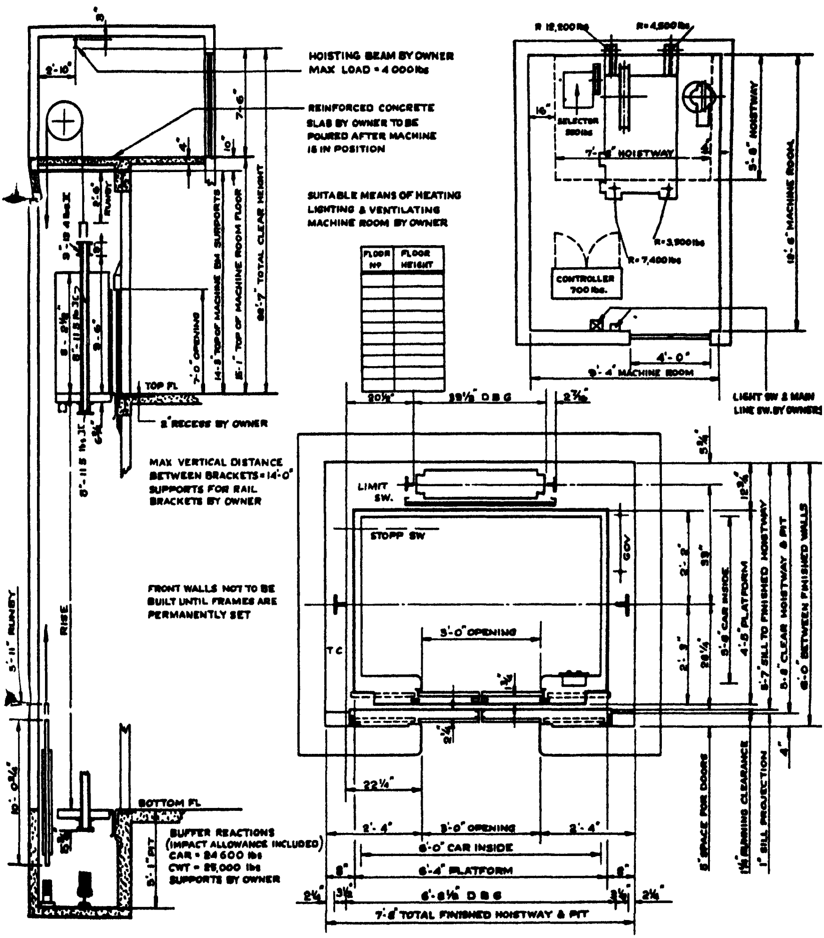


FIG. 21. TYPICAL GENERAL PURPOSE GEARED PASSENGER LIFT

(2 000 lb. at 300 ft. per min.)

(*Waygood-Otis, Ltd.*)

lifts relate to gearless lifts with single entrances and the counterweights opposite the landing entrances. The landing doors are power-operated, two-panel, centre opening. For these gearless machines, it will be noted, very large overhead clearances and pit depths are required. The reason for the large top of the well clearances is to accommodate the special

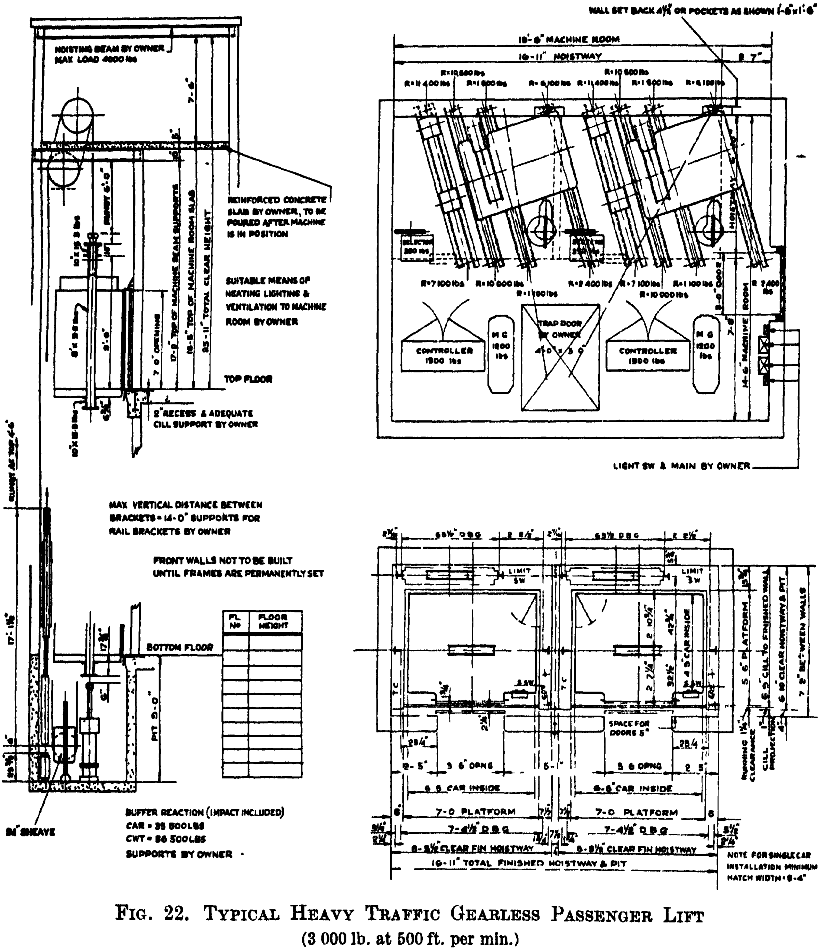



FIG. 22. TYPICAL HEAVY TRAFFIC GEARLESS PASSENGER LIFT

(3 000 lb. at 500 ft. per min.)

(*Waygood-Otis, Ltd.*)

roping arrangements needed with gearless machines. Usually a double wrap drive with two to one roping is required. The deep pit permits the use of compensating ropes, generally desirable with long travel gearless lifts. Details of a particular lift for this duty are shown in Fig. 22.

The details for general duty goods lifts on page 52 are for full

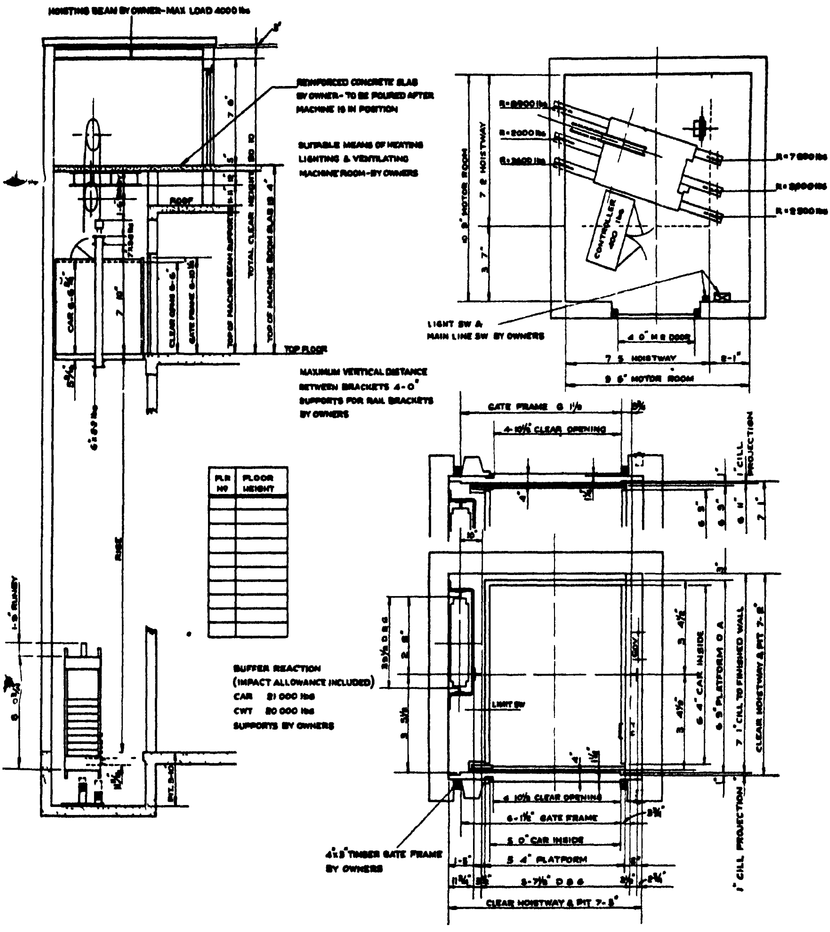


FIG. 23. TYPICAL GENERAL DUTY GOODS LIFT
(20 cwt. at 100 ft. per min.)
(*Waygood-Otis, Ltd.*)

width single entrances fitted with collapsible shutter gates. The counterweight is at one side of the well. If entrances at front and back are required, the lift well depth must be increased by two inches. The layout of a lift of this type is shown in Fig. 23.

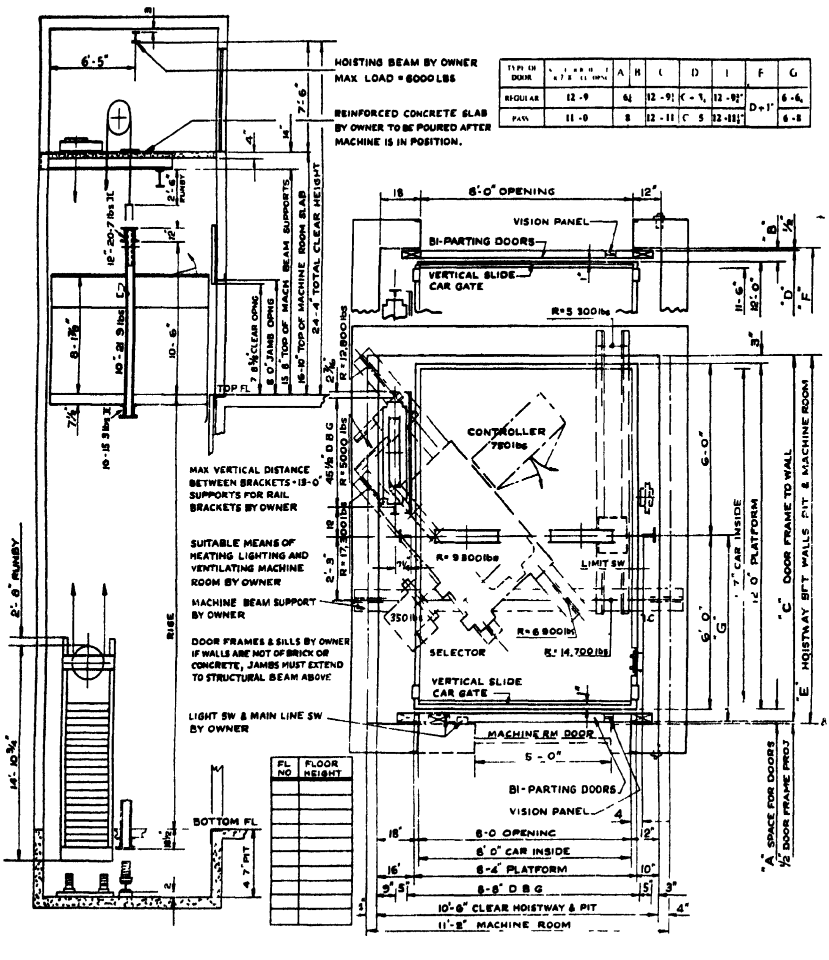



FIG. 24. TYPICAL HEAVY-DUTY GOODS LIFT

(80 cwt. at 100 ft. per min.)

*(Waygood-Otis, Ltd.)*

## TYPICAL DIMENSIONS FOR SMALL SINGLE SPEED GEARED LIFTS FOR LIGHT PASSENGER TRAFFIC

| Load | | Speed ft. per min. | Lift Well | | Machine Room | | Top Landing to Mach. Room Floor | Total Head-room | Pit Depth | Mach. Room Height | Land-ing En-trance Height | Land-ing En-trance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Per-sons | lb. | | Width | Depth | Width | Length | | | | | | | Width | Depth | |
| | | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 4 | 600 | 100 | 5 8 | 3 10 | 7 0 | 9 0 | 13 6 | 21 0 | 3 3 | 7 6 | 6 8 | 2 3 | 3 8 | 3 1 | 74 |
| 6 | 900 | 100 | 6 3 | 4 5 | 7 0 | 10 0 | 13 6 | 21 0 | 3 3 | 7 6 | 6 8 | 2 6 | 4 2 | 3 8 | 99 |
| 8 | 1 200 | 100, 150 | 6 9 | 4 10 | 8 0 | 10 0 | 14 0 | 21 6 | 3 9 | 7 6 | 6 8 | 2 9 | 4 8 | 4 1 | 112 |

## TYPICAL DIMENSIONS FOR OVERHEAD SERVICE LIFTS

| Load cwt. | Speed ft. per min. | Lift Well | | Machine Room | | Top Landing to Mach. Room Floor | Total Head-room | Pit Depth | Mach. Room Height | Land-ing En-trance Height | Land-ing En-trance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Width | Depth | Width | Depth | | | | | | | Width | Depth | |
| | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 1 | 50 100 | 3 6 | 2 7 | 5 0 | 6 0 | 9 0 | 13 0 | 3 0 | 4 0 | — | — | 2 3 | 2 3 | 20 |
| 2 | 50 100 | 3 9 | 2 10 | 6 0 | 7 0 | 9 3 | 13 3 | 3 0 | 4 0 | — | — | 2 6 | 2 6 | 27 |
| 3 | 50 100 | 4 3 | 3 4 | 6 0 | 7 0 | 9 6 | 13 6 | 3 0 | 4 0 | — | — | 3 0 | 3 0 | 37 |
| 4 | 50 100 | 4 9 | 3 9 | 6 6 | 7 6 | 10 0 | 14 0 | 3 0 | 4 0 | — | — | 3 3 | 3 3 | 52 |
| 5 | 50 100 | 5 0 | 4 0 | 6 6 | 7 6 | 10 6 | 14 6 | 3 0 | 4 0 | — | — | 3 6 | 3 6 | 70 |

## TYPICAL DIMENSIONS FOR GENERAL PURPOSE OVERHEAD GEARED PASSENGER LIFTS

| Load | | Speed ft. per min. | Lift Well | | Machine Room | | Top Landing to Mach. Room Floor | Total Head-room | Pit Depth | Mach. Room Height | Landing Entrance Height | Landing Entrance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Persons | lb. | | Width | Depth | Width | Length | | | | | | | Width | Depth | |
| | | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 8 | 1 200 | 200 | 6 4 | 5 10 | 9 0 | 13 0 | 14 9 | 22 9 | 5 0 | 8 0 | 7 0 | 3 0 | 5 0 | 4 0 | 145 |
| 10 | 1 500 | 150 | 7 4 | 5 8 | 9 0 | 13 0 | 14 9 | 22 9 | 4 0 | 8 0 | 7 0 | 3 0 | 6 0 | 4 0 | 147 |
| 10 | 1 500 | 200 | 7 4 | 5 8 | 10 0 | 13 0 | 14 9 | 22 9 | 5 0 | 8 0 | 7 0 | 3 0 | 6 0 | 4 0 | 153 |
| 10 | 1 500 | 300 | 7 4 | 5 8 | 10 0 | 14 0 | 15 0 | 23 0 | 5 0 | 8 0 | 7 0 | 3 0 | 6 0 | 4 0 | 192 |
| 13 | 2 000 | 150 | 7 8 | 6 1 | 10 0 | 13 0 | 14 9 | 22 9 | 4 0 | 8 0 | 7 0 | 3 0 | 6 4 | 4 5 | 160 |
| 13 | 2 000 | 200 | 7 8 | 6 1 | 10 0 | 14 0 | 14 9 | 22 9 | 5 0 | 8 0 | 7 0 | 3 0 | 6 4 | 4 5 | 170 |
| 13 | 2 000 | 300 | 7 8 | 6 1 | 10 0 | 15 0 | 15 0 | 23 0 | 5 3 | 8 0 | 7 0 | 3 0 | 6 4 | 4 5 | 220 |
| 16 | 2 500 | 150 | 8 4 | 6 8 | 10 0 | 14 0 | 14 9 | 22 9 | 4 0 | 8 0 | 7 0 | 3 6 | 7 0 | 5 0 | 195 |
| 16 | 2 500 | 200 | 8 4 | 6 8 | 10 0 | 15 0 | 14 9 | 22 9 | 5 3 | 8 0 | 7 0 | 3 6 | 7 0 | 5 0 | 210 |
| 16 | 2 500 | 300 | 8 4 | 6 8 | 11 0 | 15 0 | 15 0 | 23 0 | 5 3 | 8 0 | 7 0 | 3 6 | 7 0 | 5 0 | 275 |
| 20 | 3 000 | 150 | 8 4 | 7 2 | 11 0 | 13 0 | 14 9 | 22 9 | 4 3 | 8 0 | 7 0 | 3 6 | 7 0 | 5 6 | 230 |
| 20 | 3 000 | 200 | 8 4 | 7 2 | 11 0 | 14 0 | 14 9 | 22 9 | 5 3 | 8 0 | 7 0 | 3 6 | 7 0 | 5 6 | 246 |
| 20 | 3 000 | 300 | 8 4 | 7 2 | 12 0 | 16 0 | 15 9 | 23 9 | 5 3 | 8 0 | 7 0 | 3 6 | 7 0 | 5 6 | 323 |

## TYPICAL DIMENSIONS FOR GEARLESS OVERHEAD HEAVY TRAFFIC PASSENGER LIFTS

| Load | | Speed ft. per in. | Lift Well | | Machine Room | | Top Landing to Mach Room Floor | Total Head-room | Pit Depth | Mach Room Height | Landing Entrance Height | Landing Entrance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Persons | lb. | | Width | Depth | Width | Length | | | | | | | Width | Depth | |
| | | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 10 | 1 500 | 350 | 7 4 | 5 10 | 12 0 | 26 0 | 18 0 | 27 6 | 8 3 | 9 6 | 7 0 | 3 0 | 6 0 | 4 0 | 475 |
| 10 | 1 500 | 500 | 7 4 | 5 10 | 12 0 | 26 0 | 19 0 | 28 6 | 9 3 | 9 6 | 7 0 | 3 0 | 6 0 | 4 0 | 475 |
| 13 | 2 000 | 350 | 7 8 | 6 3 | 13 0 | 28 0 | 18 0 | 27 6 | 8 3 | 9 6 | 7 0 | 3 0 | 6 4 | 4 5 | 560 |
| 13 | 2 000 | 500 | 7 8 | 6 3 | 13 0 | 28 0 | 19 0 | 28 6 | 9 3 | 9 6 | 7 0 | 3 0 | 6 4 | 4 5 | 560 |
| 16 | 2 500 | 350 | 8 4 | 6 10 | 14 0 | 29 0 | 18 0 | 27 6 | 8 3 | 9 6 | 7 0 | 3 6 | 7 0 | 5 0 | 660 |
| 16 | 2 500 | 500 | 8 4 | 6 10 | 14 0 | 29 0 | 19 0 | 28 6 | 9 3 | 9 6 | 7 0 | 3 6 | 7 0 | 5 0 | 660 |
| 20 | 3 000 | 350 | 8 4 | 7 4 | 15 0 | 30 0 | 18 0 | 27 6 | 8 3 | 9 6 | 7 0 | 3 6 | 7 0 | 5 6 | 760 |
| 20 | 3 000 | 500 | 8 4 | 7 4 | 15 0 | 30 0 | 19 0 | 28 6 | 9 3 | 9 6 | 7 0 | 3 6 | 7 0 | 5 6 | 760 |
| 20 | 3 000 | 600 | 8 4 | 7 4 | 15 0 | 30 0 | 20 0 | 29 6 | 10 0 | 9 6 | 7 0 | 3 6 | 7 0 | 5 6 | 880 |
| 20 | 3 000 | 700 | 8 4 | 7 4 | 15 0 | 30 0 | 21 0 | 30 6 | 11 0 | 9 6 | 7 0 | 3 6 | 7 0 | 5 6 | 880 |

## TYPICAL DIMENSIONS FOR OVERHEAD GEARED GENERAL DUTY GOODS LIFTS

| Load cwt. | Speed ft. per min. | Lift Well | | Machine Room | | Top Landing to Mach. Room Floor | Total Head-room | Pit Depth | Mach. Room Height | Landing Entrance Height | Landing Entrance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Width | Depth | Width | Length | | | | | | | Width | Depth | |
| | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 10 | 50 | 6 4 | 4 11 | 8 0 | 10 0 | 13 9 | 21 3 | 3 0 | 7 6 | 6 6 | 4 0 | 4 4 | 4 4 | 112 |
| 10 | 100 | 6 4 | 4 11 | 8 0 | 10 0 | 13 9 | 21 3 | 3 3 | 7 6 | 6 6 | 4 0 | 4 4 | 4 4 | 112 |
| 15 | 50 | 6 10 | 5 11 | 9 0 | 11 0 | 14 0 | 21 6 | 3 3 | 7 6 | 7 0 | 4 6 | 4 10 | 5 4 | 156 |
| 15 | 100 | 6 10 | 5 11 | 9 0 | 11 0 | 14 0 | 21 6 | 4 0 | 7 6 | 7 0 | 4 6 | 4 10 | 5 4 | 162 |
| 20 | 50 | 7 6 | 6 11 | 9 0 | 13 0 | 14 0 | 21 6 | 4 0 | 7 6 | 7 0 | 5 3 | 5 7 | 6 4 | 200 |
| 20 | 100 | 7 6 | 6 11 | 9 0 | 13 0 | 14 0 | 21 6 | 4 0 | 7 6 | 7 0 | 5 3 | 5 7 | 6 4 | 218 |
| 20 | 150 | 7 6 | 6 11 | 9 0 | 13 0 | 14 6 | 22 0 | 4 6 | 7 6 | 7 0 | 5 3 | 5 7 | 6 4 | 230 |
| 30 | 50 | 8 5 | 8 5 | 10 0 | 13 0 | 14 9 | 23 6 | 4 3 | 8 9 | 7 6 | 6 0 | 6 4 | 7 10 | 280 |
| 30 | 100 | 8 5 | 8 5 | 10 0 | 13 0 | 14 9 | 23 6 | 4 3 | 8 9 | 7 6 | 6 0 | 6 4 | 7 10 | 300 |
| 30 | 150 | 8 5 | 8 5 | 10 0 | 13 0 | 15 3 | 24 0 | 5 0 | 8 9 | 7 6 | 6 0 | 6 4 | 7 10 | 312 |
| 40 | 50 | 9 8 | 9 5 | 10 0 | 14 0 | 16 0 | 25 3 | 4 6 | 9 3 | 7 6 | 7 0 | 7 4 | 8 10 | 370 |
| 40 | 100 | 9 8 | 9 5 | 10 0 | 14 0 | 16 0 | 25 3 | 4 6 | 9 3 | 7 6 | 7 0 | 7 4 | 8 10 | 400 |
| 40 | 150 | 9 8 | 9 5 | 10 0 | 14 0 | 16 6 | 25 9 | 5 3 | 9 3 | 7 6 | 7 0 | 7 4 | 8 10 | 410 |

The above dimensions are for single entrance lifts.
For two opposite entrances, add 2 inches to the well depth.

## TYPICAL DIMENSIONS FOR OVERHEAD GEARED HEAVY DUTY GOODS LIFTS

| Load cwt. | Speed ft. per min. | Lift Well | | Machine Room | | Top Landing to Mach. Room Floor | Total Head-room | Pit Depth | Mach. Room Height | Land-ing En-trance Height | Land-ing En-trance Width | Car Platform | | Top of Well Load cwt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Width | Depth | Width | Depth | | | | | | | Width | Depth | |
| | | ft. in. | ft. in. | ft. in. | ft. ft. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | |
| 30 | 50, 100 | 8 10 | 8 10 | 9 6 | 14 0 | 16 0 | 24 6 | 4 6 | 8 6 | 7 6 | 6 0 | 6 4 | 8 0 | 282 |
| 30 | 150 | 8 10 | 8 10 | 9 6 | 14 0 | 16 0 | 24 6 | 4 8 | 8 6 | 7 6 | 6 0 | 6 4 | 8 0 | 290 |
| 40 | 50, 100 | 9 10 | 9 10 | 10 6 | 14 0 | 16 6 | 24 6 | 4 6 | 8 6 | 7 6 | 7 0 | 7 4 | 9 0 | 368 |
| 40 | 150 | 9 10 | 9 10 | 10 6 | 14 0 | 16 6 | 25 6 | 5 1 | 9 0 | 7 6 | 7 0 | 7 4 | 9 0 | 404 |
| 60 | 50, 100 | 11 0 | 12 4 | 11 6 | 15 0 | 17 0 | 26 0 | 4 8 | 9 0 | 7 6 | 8 0 | 8 4 | 11 6 | 539 |
| 60 | 150 | 11 0 | 12 4 | 11 6 | 15 0 | 17 0 | 26 0 | 5 4 | 9 0 | 7 6 | 8 0 | 8 4 | 11 6 | 558 |
| 80 | 50, 75 | 11 0 | 15 4 | 12 0 | 16 0 | 17 6 | 26 6 | 5 4 | 9 0 | 8 0 | 8 0 | 8 4 | 14 6 | 713 |
| 80 | 100 | 11 0 | 15 4 | 12 0 | 16 0 | 17 6 | 26 6 | 5 4 | 9 0 | 8 0 | 8 0 | 8 4 | 14 6 | 752 |
| 100 | 50, 75 | 13 2 | 15 4 | 13 0 | 17 0 | 17 6 | 27 0 | 5 6 | 9 6 | 8 0 | 10 0 | 10 4 | 14 6 | 884 |
| 100 | 100 | 13 2 | 15 4 | 13 0 | 17 0 | 17 6 | 27 0 | 5 6 | 9 6 | 8 0 | 10 0 | 10 4 | 14 6 | 935 |

The above dimensions are for single entrance lifts. For two opposite entrances, add 7 in. to the well depth.

For heavy duty goods lifts the figures on page 53 are for single entrances fitted with vertical bi-parting power-operated doors. To accommodate these doors a minimum floor to floor height of

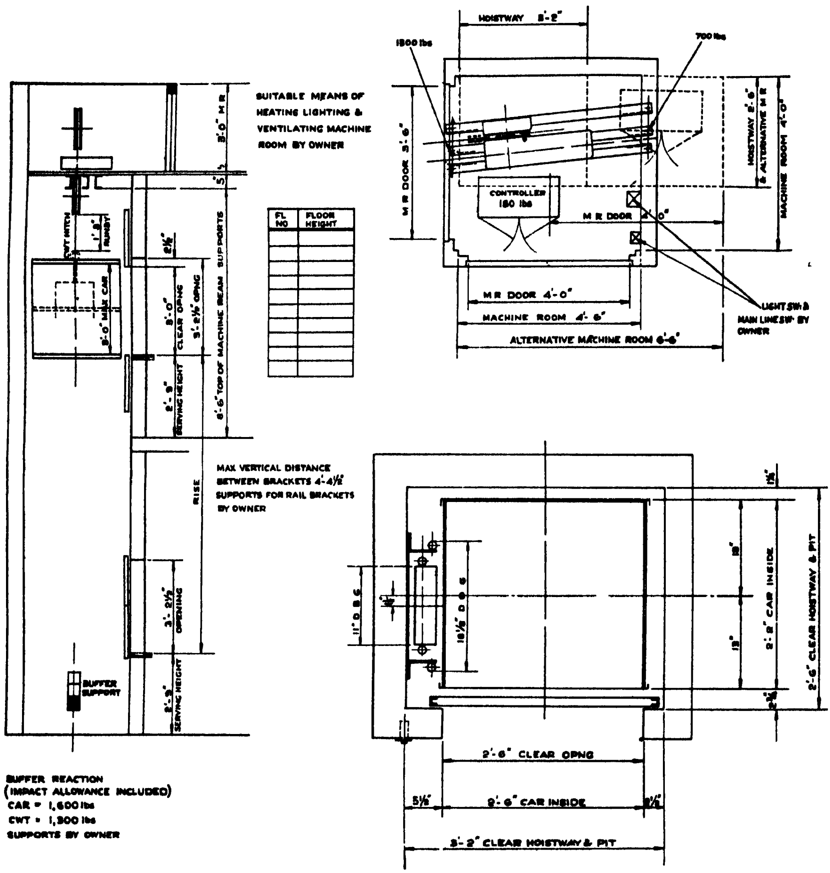



FIG. 25. TYPICAL SERVICE LIFT
(2 cwt. at 100 ft. per min.)
(*Waygood-Otis, Ltd.*)

12 ft. is required. If entrances at the front and back are necessary, the depth of the well must be increased by 7 in. Details of the layout of a heavy duty goods lift of this type are shown in Fig. 24.

TYPICAL DIMENSIONS FOR BASEMENT MACHINE ROOMS

| Load | | Machine Room Width | Machine Room Depth | Mach. Room Height | Pent-house Height | Top of Well Load |
|---|---|---|---|---|---|---|
| | cwt. | ft. in. | ft. in. | ft. in. | ft. in. | cwt. |
| | 1 | 5 0 | 7 0 | 7 0 | 4 0 | 31 |
| | 2 | 6 0 | 8 0 | 7 0 | 4 0 | 46 |
| | 3 | 6 0 | 8 0 | 7 0 | 4 0 | 60 |
| | 4 | 6 6 | 8 6 | 7 0 | 4 0 | 83 |
| | 5 | 6 6 | 8 6 | 7 0 | 4 0 | 102 |
| Persons | lb. | | | | | |
| 4 | 600 | 7 0 | 11 0 | 8 0 | 4 6 | 107 |
| 6 | 900 | 7 6 | 12 0 | 8 0 | 4 6 | 159 |
| 8 | 1 200 | 8 0 | 14 0 | 8 0 | 5 0 | 213 |
| 10 | 1 500 | 8 6 | 15 0 | 8 0 | 5 0 | 246 |
| 15 | 2 250 | 9 0 | 16 0 | 8 0 | 5 6 | 330 |
| 20 | 3 000 | 9 6 | 18 6 | 9 0 | 5 6 | 410 |

Suitable dimensions for service lifts from 1 to 5 cwt. capacity are shown in the table on page 49. The speed of these small lifts is either 50 or 100 ft. per minute. The general layout of a service lift is shown in Fig. 25.

When, for any reason, an overhead machine room is not possible, the equipment is usually installed in the basement and for such installations the data in the table on this page are representative of good practice.

Substantial rolled steel joists or reinforced concrete beams will be required in the machine room floor to carry the lift loads. If the machine is above the well, the total load to be supported will be the sum of the weights of the machine, car, load, counterweight, controller, and sundry other small gear. The greater part of this load is "live," and the supporting joists must therefore be designed to carry double the "dead" load,

and, further, as the load is unequally distributed, comparatively large section joists are necessary. In calculating the size of the overhead supporting beams, the total load is taken to be

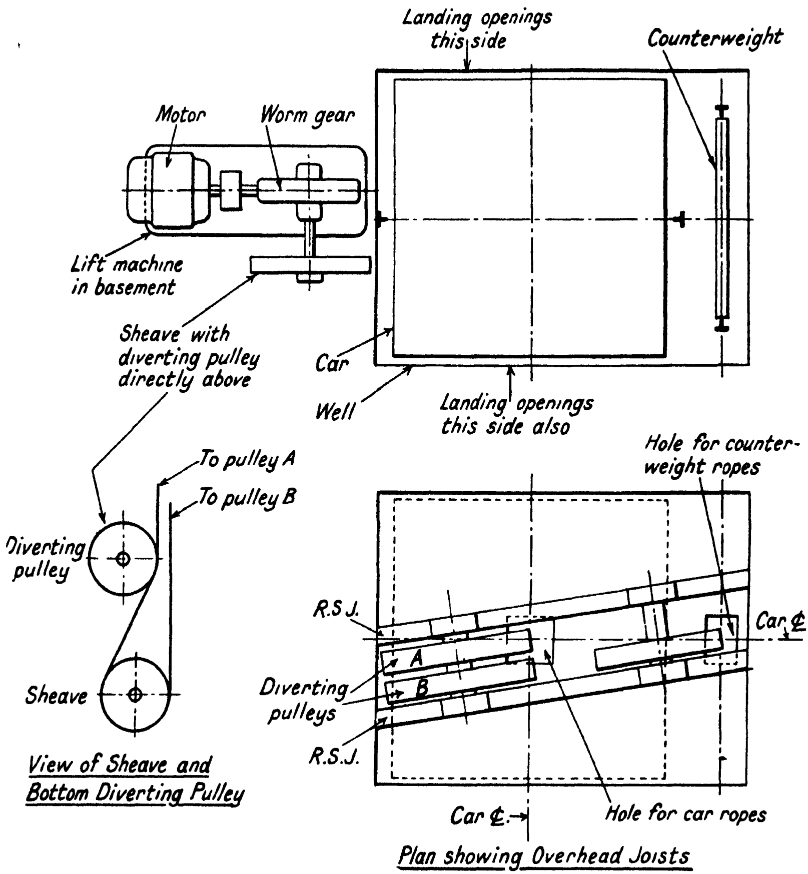



FIG. 26. DETAILS OF TRACTION DRIVE WITH MACHINE BELOW

the weight of all the equipment resting on the beams plus twice the maximum static load suspended from the beams. The load resting on the beams includes the complete weights of the winding machine, sheaves, controller and all auxiliary equipment and the load suspended from the beams includes the

sum of the tensions of all ropes suspended from the beams. The latter is the "live load" which must be doubled to allow for impact and acceleration stresses. Factors of safety of 5 and 7 are allowed for steel and concrete respectively in designing the beams, the deflection of which, with loads as stated above, should not exceed $\frac{1}{2500}$ of the span. The actual arrangement of

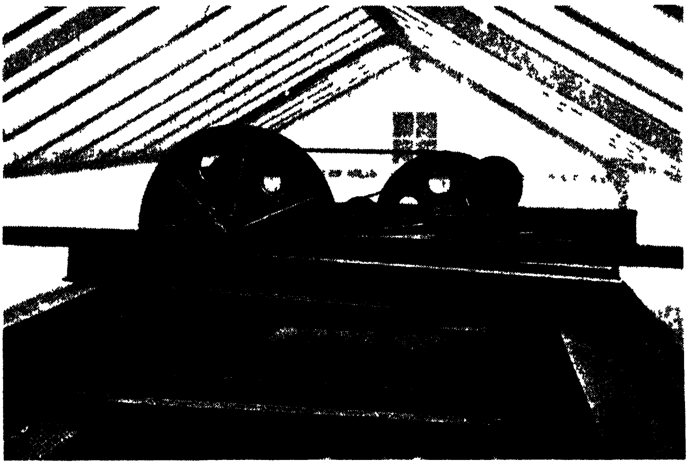


FIG. 27. OVERHEAD JOISTS AND PULLEYS
*(Marryat & Scott)*

these joists depends upon the lay-out of the machine, typical supporting joists being shown in Figs. 20–25.

In the tables on pages 49-53 the load quoted is the equivalent dead load at the top of the well. This is the load due to the tensions in the suspending ropes and to the weight of the winding machine and does not include the weights of the controller, motor generator set or any other auxiliary equipment. For an overhead geared 2-speed motor drive, the weight of the controller and other gear amounts to about 10 per cent of the overhead well load quoted. If a variable voltage drive is used, the weight of the overhead control gear, motor generator set and other equipment, will be approximately 20 per cent of the overhead loads stated in the tables.

With the basement location, overhead joists will be required

to support a total load equal to twice the sum of the weights of car, load, and counterweight, and as this is a "live" load, the equivalent "dead" load will be twice this figure. Overhead

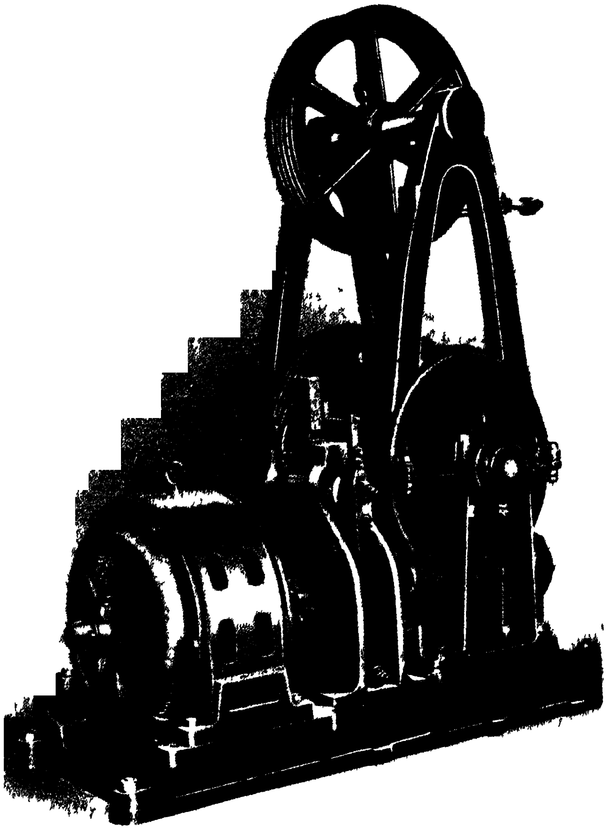


FIG 28. BASEMENT MACHINE
(*Waygood-Otis, Ltd*)

joist arrangements for basement machines are shown in Figs. 26 and 27.

The overhead well loads shown on page 55 for basement machines are also the total top loads as all the equipment,

except the overhead load supporting pulleys, is located in the basement. A basement winding machine with the diverting pulley mounted on the machine is shown in Fig. 28, and this arrangement eliminates the necessity of supporting the pulley by structural steelwork fixed to the building. Lifting joists must also be fixed in the motor room to enable the machine to be placed in position and to allow of ready removal of any part for repair or renewal. A permanent danger notice should be displayed on the outside of the door and one near the machinery and the room should be kept locked.

**Noise.** In some buildings, notably hospitals, silence is of paramount importance, and various measures must be adopted if it is desired to reduce the lift noise to the lowest possible level. This is generally a difficult problem, as with modern steel-framed buildings noise is readily transmitted to rooms which may be at a considerable distance from the motor room. When silence is important, it is usually better to accommodate the lift machine in the basement.

In dealing with the problem of noise it is necessary first to reduce the noise generated in the motor room itself to a minimum. A reasonably silent motor may be obtained by carefully selecting the type, paying due regard to its design, and by employing plain bearings. Motors fitted with commutators should have the micas undercut and the brushes carefully bedded. Motor hum may be considerably reduced by using a motor frame size larger than that required to give the necessary horse-power output and thus working the magnetic circuit below its saturation point Brake noises will be diminished if the brake is immersed in oil, and often by incorporating torque motor brakes instead of the usual type, whilst hum due to a.c. brakes can be reduced by using shaded poles, i.e. inserting copper loops in the face of each magnet core. The gearing should be silent in operation if the gear teeth are accurately cut, and the same applies to gearing on floor selectors. Considerable noise emanates from the controller switches during the starting, acceleration and stopping periods, and only by giving attention to design or totally enclosing the controller is it possible to diminish these noises to a negligible amount.

Totally enclosed controllers are shown in Figs. 2 and 8.

Having eliminated the noises generated in the machine room

as much as possible, our next step is to prevent that which remains from being transmitted to other parts of the building. Direct transmission of noise by the air can be reduced by lining the machine room walls with some sound insulating material such as Cabot's quilting or "Absorbit." Noise transmitted via the well may be greatly diminished by providing a free circulation of air between the machine room floor and the top of the well. This entails building a false floor about 3 ft. below the machine room floor and ensuring a free circulation of air through this space. Vibration transmitted by the building structure can be reduced by inserting slabs of compressed cork or similar material between the concrete bed on which the machine baseplate rests and the supporting joists. As an additional precaution, the ends of the joists may be surrounded by insulating material in boxes before bedding in the walls.

Other lift noises are due to the motion of the car and counterweight in the well, and to the operation of gates and doors. The former may be diminished by fitting a retiring lock release cam to the car and thus preventing the cam from hitting the gate lock striker arm when passing landings. The noise due to the motion of the car and counterweight on their guides may be prevented from being transmitted to adjacent rooms by inserting a felt sleeve round each guide fixing bolt. A more complete but also more expensive method of effecting this is to construct double well walls, the inner wall carrying the guides, the intervening space forming a sound absorbing chamber. Gate noises may be reduced by the insertion of rubber buffers between the pickets, rubber bumpers at the extremes of travel, and by fitting hardwood bottom gate tracks instead of steel tracks.

# CHAPTER III

## TYPES OF DRIVE

Two types of drive are employed for lift work, namely, the *traction* or *sheave* drive, and the *drum* drive.

### TRACTION DRIVE

In this case one set of ropes is used, the ropes passing from the car round a cast-iron or steel grooved sheave and thence to the counterweight. Friction between the ropes and the sheave grooves therefore supplies the force necessary to raise or lower the car. The sheave is secured to a turned mild steel shaft by two sunk keys at right angles to each other. Alternatively, keys may be eliminated by bolting the sheave rim to a gear and sheave centre. This centre is a casting with two flanges, one of which carries the sheave, the other carrying the worm-wheel rim, the shaft being pressed into the bore of the centre, an example of which is shown in Fig. 30. The outer end of the driving shaft is carried in a pedestal bearing fitted with readily renewable bearings of gunmetal or white metal, preferably of the split pattern, in order to compensate for wear. Sometimes the sheave shaft is supported in tapered roller bearings. In those cases in which no outer shaft bearing is employed, the outer edge of the sheave is fitted with an extended flange to minimize the danger of the ropes leaving the sheave. A lift machine with no outer bearing is shown in Fig. 29.

The main advantage of the traction drive is that if either the car or counterweight comes into contact with the buffers, the drive ceases and there is no danger of the car being wound into the overhead structure, as would be possible with a drum machine. With very high rises, however, as are met with in America, overwinding of the car may be possible if the counterweight is on its buffers. The weight of the ropes on the counterweight side may be sufficient to provide traction to drive the ropes. In such cases special precautions are taken to prevent this occurring. Other advantages of this method are cheapness, simplicity, and the fact that standard equipment may be used irrespective of the height of travel. A view of a typical traction

machine is shown in Fig. 30 which consists of a two-speed a.c. motor, a d.c. electromagnetic brake, worm gearing and a sheave supported in roller bearings.

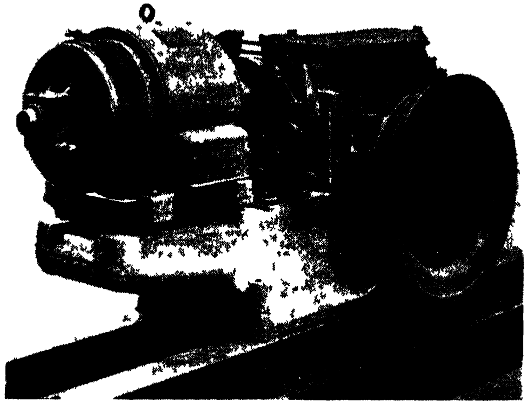


FIG. 29. LIFT MACHINE WITH NO OUTER SHEAVF BEARING
*(Wm Wadsworth & Sons)*

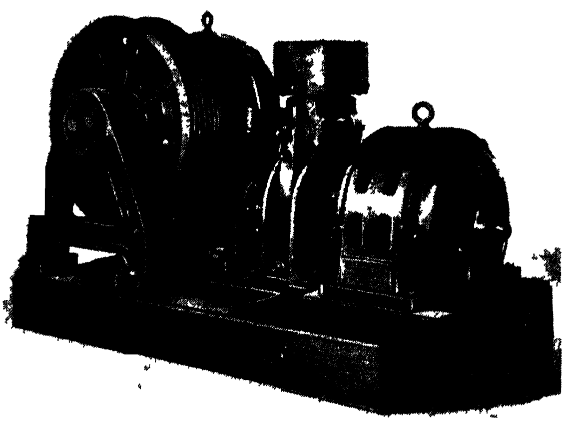


FIG 30 TYPICAL UNDER-TYPE GEARED WINDING MACHINE
*(Waygood-Otis, Ltd )*

**Sheaves.** Sheave is the name given to a pulley to which power is applied, and is that part of the lift machine transmitting driving power to the lift ropes The sheave is of disc

construction, i.e. without spokes, and to ensure a long life for the ropes the sheave diameter should be as large as practicable, the minimum depending upon the rope diameter, material and construction, and the maximum car speed. A larger diameter sheave should be employed for Seale or Warrington ropes than

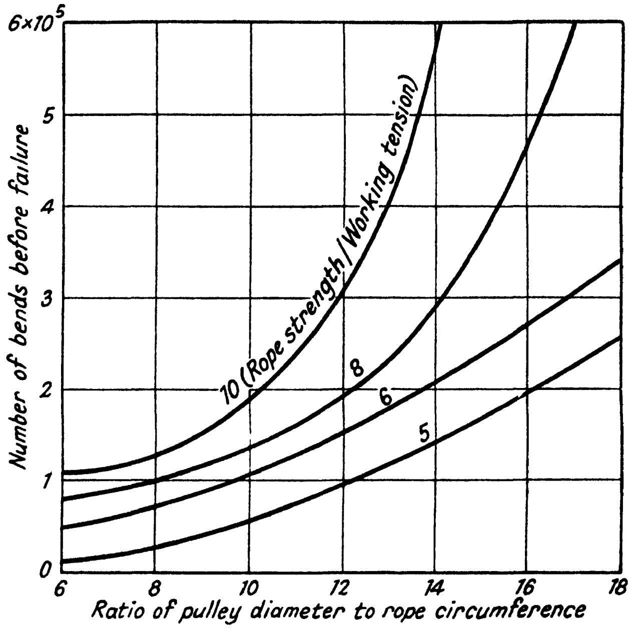



FIG. 31. GRAPH SHOWING RELATION BETWEEN NUMBER OF BENDS BEFORE FAILURE AND INCREASING PULLEY DIAMETER
(*Junior Institution of Engineers Journal*)

for ropes of uniform construction, whilst ropes of low tensile strength and consequently high ductility may be used with sheaves of smaller diameter than high tensile strength ropes would require. The ratio of the sheave diameter to the rope diameter should be not less than $(0{\cdot}015S + 37)$ with a minimum value of 40. This formula, in which $S$ is the rope speed in feet per minute, is applicable to all the main eight types of rope described in Chapter IV, with the exception of the $6 \times 19$ (9/9/1) Seale which is stiffer than the other seven constructions.

For this Seale rope the formula should be modified to $(0{\cdot}015S + 44)$ with a minimum value of 47.

For service lifts, the ratio of sheave diameter to the rope diameter should be not less than 30.

The importance of specifying a large sheave diameter is clearly shown in Fig. 31,* which is a graph showing the relation between the number of bends before failure and increasing sheave diameters for different values of the ratio $\frac{\text{rope strength}}{\text{working tension}}$. The graph is plotted from results obtained during a test taken on a sample of $\frac{6}{16}$ ordinary lay rope. It also shows that the rope performance is improved if this ratio is large.

The type of sheave groove usually employed is vee-shaped, having an included angle of from 35° to 40°. With a small groove angle the traction is large, but it is necessary to use hard ropes so as to minimize rope wear. Details of a typical vee-grooved traction sheave are shown in Fig. 32. On modern high-speed lifts a U-groove, similar to that used on a drum or pulley, is frequently employed, but the traction is so low with this groove as to necessitate the use of the double-wrap method of roping. The U-groove, however, has the advantages of longer rope life and a greater degree of silence, the latter being particularly noticeable at the higher car speeds of 600 ft. per min. and over. Other types of sheave groove sometimes used (Fig. 33) are a modified form of vee-groove and an undercut groove, these being compromises between the vee- and U-types. In the round-seat undercut groove the rope seats are the same radii as the pulley grooves, and the width of the undercut should not exceed 0·8 of the diameter of the rope. The rope unit pressure with this groove is greater than with a "U"-groove, but not as severe as the vee-groove.

The grooves of a traction sheave must be maintained in good condition as any uneven wear which would cause, say, one rope to run deeper in its groove than the other ropes, will result in this rope travelling slower than the others and consequently slipping in its groove in its efforts to keep pace with the other ropes.

* "Wire Ropes," paper by W. A. Scoble read before the Junior Institution of Engineers.

It will be appreciated that all traction drives rely for their effectiveness upon friction between the ropes and the sheave grooves, the tractive force available depending upon the

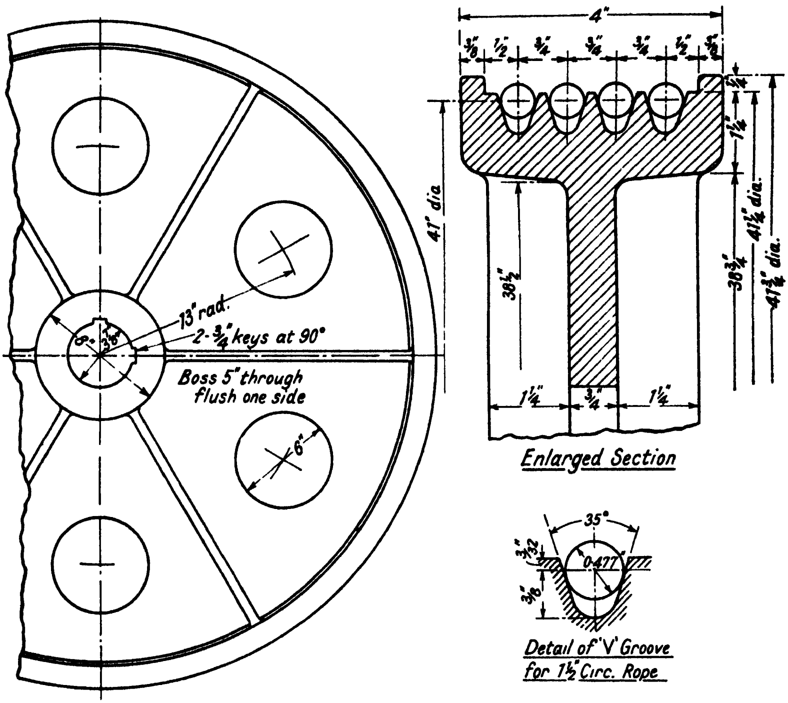



FIG. 32. VEE-GROOVED SHEAVE FOR 1¾ IN. CIRCUMFERENCE ROPES AND 41 IN. ROPE CENTRE DIAMETER

(*R. J. Shaw & Co.*)

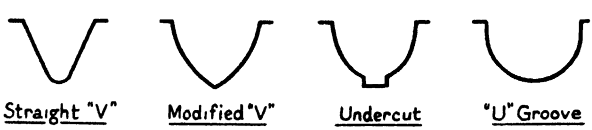



FIG. 33. TYPES OF GROOVE

coefficient of friction between the ropes and the sheave, the groove angle, and the amount of rope wrap. These three factors govern the ratio which can exist between the rope tensions on the two sides of the sheave before slipping occurs.

This maximum ratio between the rope tensions on the "tight" and "slack" sides of the sheave may be calculated as follows for both single-wrap and double-wrap drives.

Single-wrap Drive. In Fig. 34 let

$T_1$ = tension on tight side of rope.
$T_2$ = " " slack " "
$\theta$ = angle subtended by that portion of the rope in contact with the sheave.
$bc$ = indefinitely small portion of $BC$.
$d\theta$ = angle subtended by $bc$
T = tension in rope at $c$.
$T + dT$ = " " " $b$.
S = resultant pressure of the sheave on portion $bc$ of rope.
$\mu$ = coefficient of friction between rope and sheave.

Then at the moment when slipping occurs

$$(T + dT) - T = \mu S.$$

but $S = T \cdot d\theta$ .... (Triangle of forces, Fig. 34 ($b$).)

$$\therefore \quad dT = \mu T d\theta.$$

$$\therefore \quad dT/T = \mu d\theta.$$

$$\therefore \quad \int_{T_2}^{T_1} \frac{dT}{T} = \mu \int_0^{\theta} d\theta.$$

$$\therefore \quad \log_e (T_1/T_2) = \mu\theta, \text{ or } T_1/T_2 = e^{\mu\theta} \quad \ldots \ldots \quad (1)$$

Since, however, the rope lies in a vee-groove as shown in Fig. 34 ($c$), the effect is to increase the resistance to slipping due to the wedging action between the two surfaces. The resistance to slipping in element $bc$ is $2\mu R$.

But from Fig. 34 ($d$), $S = 2R \sin \alpha$, where $2\alpha$ is the angle of the groove.

$$\therefore \quad 2R = S \operatorname{cosec} \alpha.$$

Hence the resistance to slipping in $bc$ is $\mu S \operatorname{cosec} \alpha$.

In equation (1) above, in which the effect of the vee-groove has been neglected, the resistance to slipping in $bc$ was $\mu S$. For this equation to be applicable to a rope in a vee-groove it is,

therefore, necessary to substitute $\mu$ cosec $\alpha$ for $\mu$ and the equation then becomes

$$T_1/T_2 = e^{\mu\theta \operatorname{cosec} \alpha} \quad \ldots \quad (2)$$

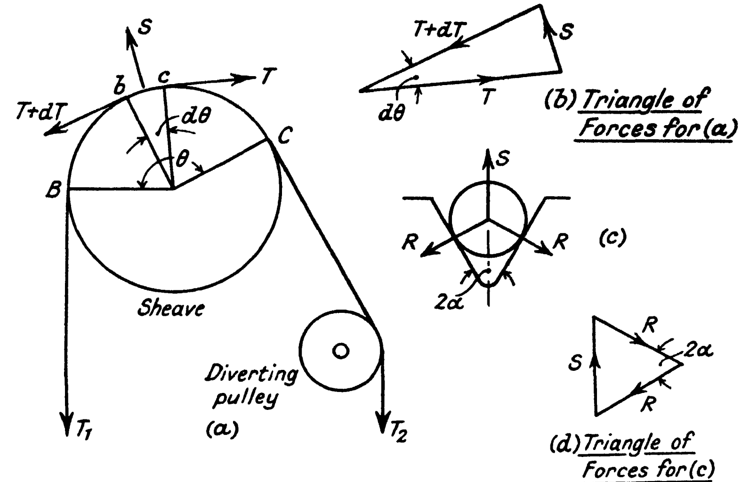



FIG. 34. ROPE AND SHEAVE FORCES IN SINGLE-WRAP DRIVE

It will be observed from equation (2) that when an idle pulley is employed and the angle $\theta$ is thereby reduced, the traction is consequently less. To be rigidly accurate, the area of contact should be considered as $\mu$ is a function of the unit pressure.

DOUBLE-WRAP DRIVE (see Chapter IV). Using symbols as shown in Fig. 35

$$T_1/T_3 = e^{\mu\theta_1 \operatorname{cosec} \alpha}$$

and $$T_3/T_2 = e^{\mu\theta \operatorname{cosec} \alpha}.$$

$$\therefore \; T_1/T_2 = (T_1/T_3) \times (T_3/T_2)$$

$$= e^{\mu\theta_1 \operatorname{cosec} \alpha} \times e^{\mu\theta \operatorname{cosec} \alpha}.$$

$$\therefore \; T_1/T_2 = e^{\mu \operatorname{cosec} \alpha \, (\theta + \theta_1)}.$$

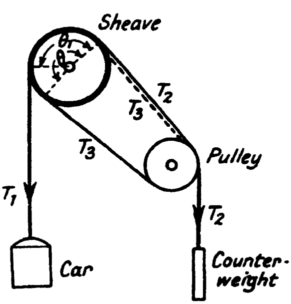



FIG. 35. DOUBLE-WRAP DRIVE

The traction is therefore increased by employing the double-wrap drive.

**Coefficient of Friction.** From the above equations it is observed that the maximum ratio of rope tensions is a function of the coefficient of friction between the ropes and sheave. The minimum value of the coefficient of friction necessary to drive a lift car in any particular installation may be calculated as follows.

Assume that the weights of the car and load are 3 000 lb. and 2 000 lb. respectively, and that the maximum speed of travel is 400 ft. per min.

$$\text{Let counterweight} = \text{car} + 50\%\ \text{load}$$
$$= 4\,000\ \text{lb.}$$

If the car reaches its maximum speed in 2 sec., then the average acceleration is $400/120 = 3{\cdot}3$ ft. per. sec. per sec. The maximum rate of acceleration may be taken as 6·6 ft. per sec. per sec.

After acceleration is completed, $T_1/T_2 = 5\,000/4\,000$.

During the period of maximum acceleration when the tendency to slip is greatest, $\dfrac{T_1}{T_2} = \dfrac{\left(5\,000 + \dfrac{5\,000 \times 6{\cdot}6}{32{\cdot}2}\right)}{4\,000 - \dfrac{4\,000 \times 6{\cdot}6}{32{\cdot}2}} = 1{\cdot}9.$

From above $T_1/T_2 = e^{\mu\theta \operatorname{cosec} \alpha}$.

If $\theta = 180°$ and $2\alpha = 40°$;

then $e^{\mu\pi \operatorname{cosec} 20°} = 1{\cdot}9.$

$\therefore \quad \mu = (\log_e 1{\cdot}9)/\pi \operatorname{cosec} 20° = 0{\cdot}07.$

For a steel cable on a cast-iron sheave the value of $\mu$ varies from approximately 0·15 to 0·40 as the surface pressure increases from 100 lb. per in.$^2$ to 600 lb. per in.$^2$ These figures are for dry surfaces, but the value of $\mu$ may possibly be as low as 0·06 if the cables are greasy. Hence the importance of ensuring that the amount of lubricant used is kept to a minimum.

**Diverting Pulleys.** These are idle pulleys used to change the direction of the ropes. With both drum and traction machines it is frequently necessary to employ pulleys to divert the ropes from the sheave or drum to the well. These pulleys are of

similar construction to the sheaves, but the grooves are arcs of circles for a distance equal to one-third of the circumference of the rope. The radius of the groove should be larger than the radius of the rope by one-twentieth to accommodate ropes 5 per cent over nominal size, as most new ropes are oversize.

The pulley diameter is determined in a similar manner to that described for sheave diameters, and a fact which must be borne in mind is that if the rope is bent to the curvature of the pulley, then a small angle of contact has the same effect on the rope as a large angle. It is, therefore, incorrect to assume that if the angle of contact is small a smaller pulley may be employed. A pulley is shown in Fig. 36.

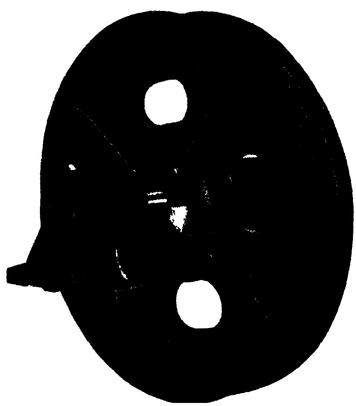


FIG. 36. DIVERTING PULLEY
(*J. & E. Hall, Ltd.*)

### DRUM DRIVE

In a drum drive, one end of the car ropes and one end of the counterweight ropes are securely fastened by clamps on the inside of a cast-iron or steel drum, the other ends being fastened to the car and counterweight respectively. One set of ropes is wrapped clockwise round the drum and the other set anti-clockwise, hence when one set is unwrapping the other is being wrapped on the drum. There should be not less than one complete turn of the ropes on the drum when the car or counterweight has reached the extreme limit of its travel and clearance. As the car travels, the ropes move along the drum in spiral grooves cut on its periphery, the grooves being similar in radii to those described for pulleys, but their depths should be not less than one-third of the diameter of the rope. The pitch of the groove should be such that there is a clearance of not less than $\frac{1}{16}$ in. between parts of the rope when coiled on the drum. The drum diameter should be as large as practicable in order to obtain a satisfactory rope life, the minimum diameter being determined in a similar manner to that described for sheave diameters.

The disadvantage of the drum drive is that as the height of travel increases, the drum becomes unwieldy, and it is therefore seldom used for rises of more than 100 ft. Because of the many advantages of the traction method, the drum is now almost obsolescent.

# CHAPTER IV

## ROPING SYSTEMS AND ROPES

SEVERAL different roping schemes are employed to transmit power from the winding machine to the car. The actual method adopted depends upon local conditions; the situation of the winding machine, and the speed and loading of the car. It is, however, important that particular care should be given to the selection of the roping system, as upon this depends, to a large extent, the life which will be obtained from the lifting ropes. The roping should be as simple as possible and employ the minimum number of pulleys.

The lift machine is usually situated either near the top of the well or as near to the bottom of the well as practicable, but the location which permits of the best and cheapest roping scheme is immediately above the well. Further advantages of the top of the well position are a lower lift capital cost, reduced power consumption and the loads on the overhead structure are usually smaller than with the machine in the basement, the overhead loads for the two positions being as follows—

(*a*) *Machine Overhead.*

Load = Lift machine + Control gear + Car + Car Load + Counterweight.

(*b*) *Machine Below.*

Load = 2 (Car + Car Load + Counterweight).

The loadings in the two cases are shown in Fig. 37. Hence, in the event of the lift machine (motor, brake, and gearing) together with the control gear weighing more than the combined weights of the car, load, and counterweight, the overhead beams will be subjected to smaller loads with the basement location than if the machine is overhead. For lifts working in hospitals and other buildings where silence is of paramount importance, it is usually advisable to install the machine in the basement. The effective silencing of an overhead installation involves considerable additional cost in providing a specially built insulated motor room. An intermediate floor is sometimes

utilized for the winding machine when it is not permissible to install in the top or bottom positions.

**Traction Drives.** The traction drive shown in Fig. 38 (*a*) is the simplest of all roping schemes and is employed wherever possible. It is sometimes called the *half-wrap* or *single-wrap, one-to-one* system, because the ropes wrap the traction sheave once only (for approximately 180°) and the peripheral speed of the sheave is equal to the car speed. On account of the small arc of contact, a vee-sheave together with comparatively hard

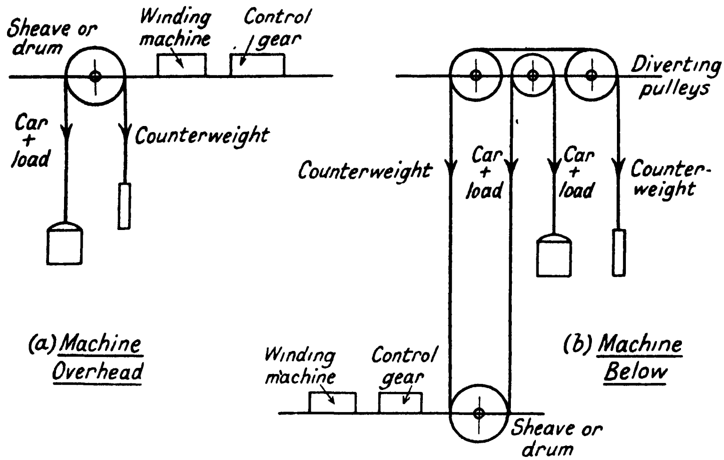



FIG. 37. DIAGRAM SHOWING LOADS ON OVERHEAD STRUCTURES

ropes is used. When the diameter of the sheave can be made equal to the distance between the car and counterweight supports, a diverting pulley is unnecessary.

A *double-wrap* drive, sometimes referred to as a *full-wrap* or *cross-over* drive, is shown in Fig. 38 (*b*). The lifting ropes pass from the car around the sheave, pulley, sheave again, pulley, and thence to the counterweight if the pulley is not directly under the sheave. It is thus seen that the ropes wrap the sheave for approximately 360°. The pulley is placed directly under the sheave as in Fig. 38 (*b*) when the dimensions of the car and sheave permit. Most modern high-speed gearless lifts make use of this double-wrap drive which, because of the

increased rope wrap, allows the use of U-shaped grooves on the sheave. This drive is also employed where the out-of-balance load is large, and there might be danger of rope slip with a half-

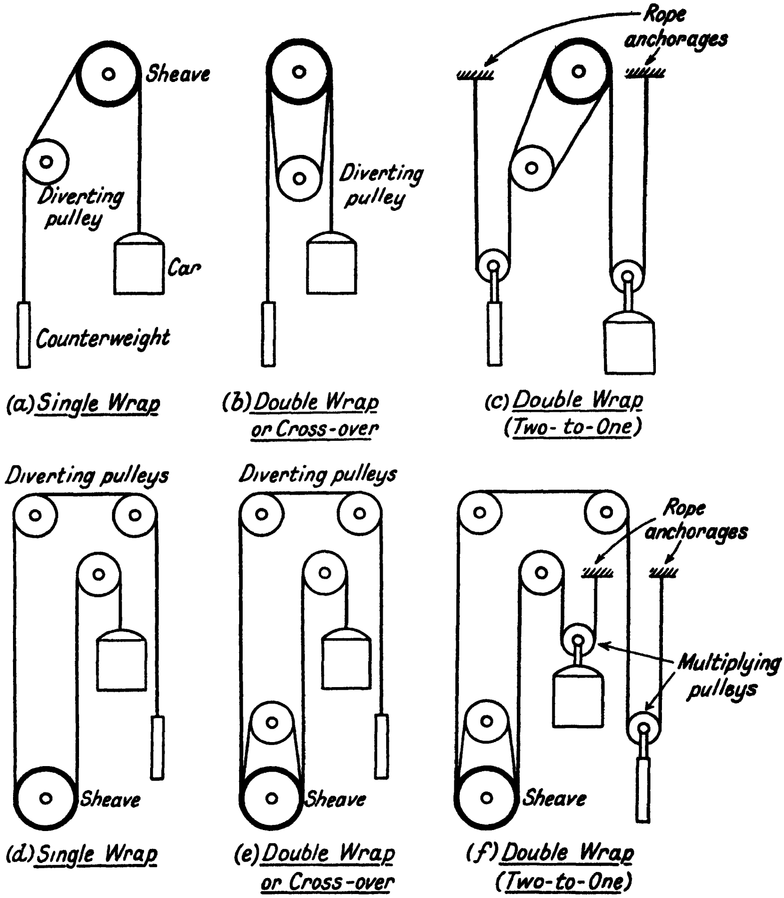



FIG. 38. SYSTEMS OF ROPING FOR TRACTION DRIVE

wrap system. With a full-wrap drive the load on the sheave bearings is double that with a single-wrap drive and, of course, the frictional resistance is considerably greater. It should be noted that in these roping sketches only one rope is shown, but the number used may be as many as six, or even eight, whilst the

minimum number which should be employed is two. Therefore, if six ropes are used with a double-wrap drive, then twelve grooves will be required on the sheave and twelve on the pulley when the pulley is not directly under the sheave.

Fig. 38 (*c*) shows a *double-wrap, two-to-one* roping system which gives a peripheral sheave speed of twice the car speed. The ropes are securely anchored to one of the structural beams and then pass round a multiplying pulley fixed to the counterweight, pulley, sheave, pulley, sheave, a second multiplying pulley

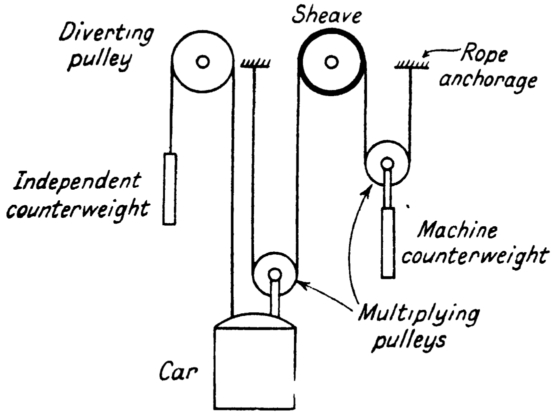



FIG 39. SINGLE-WRAP TWO-TO-ONE ROPING
(Two counterweights)

fixed to the car frame, and finally to a second anchorage. This is usually employed on large capacity slow-speed goods lifts with the object of removing a portion of the load from the winding machine and, further, of permitting the use of a smaller number of lifting ropes, since these are not subjected to such stresses as with a one-to-one roping system. The two-to-one roping also enables gearless machines to be used for comparatively low car speeds of about 200 ft. per min. A disadvantage of the method, however, is the comparatively short rope life obtained due to the reverse bends employed.

For very heavy duty lifts, a method which has been employed still further to reduce the load carried by the winding machine makes use of a second counterweight as shown in Fig. 39. The

addition of this independent counterweight causes some loss of traction, and its mass must be sufficiently low, therefore, to allow enough weight on the machine counterweight to maintain adequate traction. This lightening of the machine load is particularly desirable in the case of large gearless machines where the whole load, plus the weight of the motor, is normally carried by the motor bearings.

Fig. 38 (*d*), (*e*), and (*f*) show roping schemes similar to Fig. 38 (*a*), (*b*), and (*c*) respectively, but with the winding machine located below the well.

Another drive which has been used in recent years for high-speed gearless machines introduces a 3 : 1 speed ratio between the motor and the car. This is shown diagramatically in Fig. 40. The advantage of this drive is that it permits the gearless machine to be used for low car speeds or for a given car speed; it enables the motor to be run at a higher speed than would be necessary if a 1 : 1 or 2 : 1 drive was employed. This results in a more stable motor control with smoother acceleration and more accurate levelling.

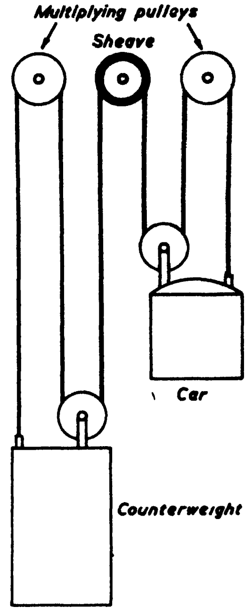



FIG. 40. THREE-TO-ONE ROPING

**Drum Drives.** A simple drum drive is shown in Fig. 41 (*a*), in which both car and counterweight ropes are securely anchored to the drum, and then pass to the car and counterweight respectively, via idle pulleys where necessary.

In the drive shown in Fig. 41 (*b*) an independent counterweight is employed in addition to the normal machine counterweight. The effect of this independent counterweight is to remove part of the car load from the drum shaft bearings and enable the machine counterweight to be reduced. These two counterweights are sometimes employed on large goods lifts, the independent counterweight being about 400 lb. lighter than the machine counterweight. Both counterweights run in the same guides, with the independent counterweight above,

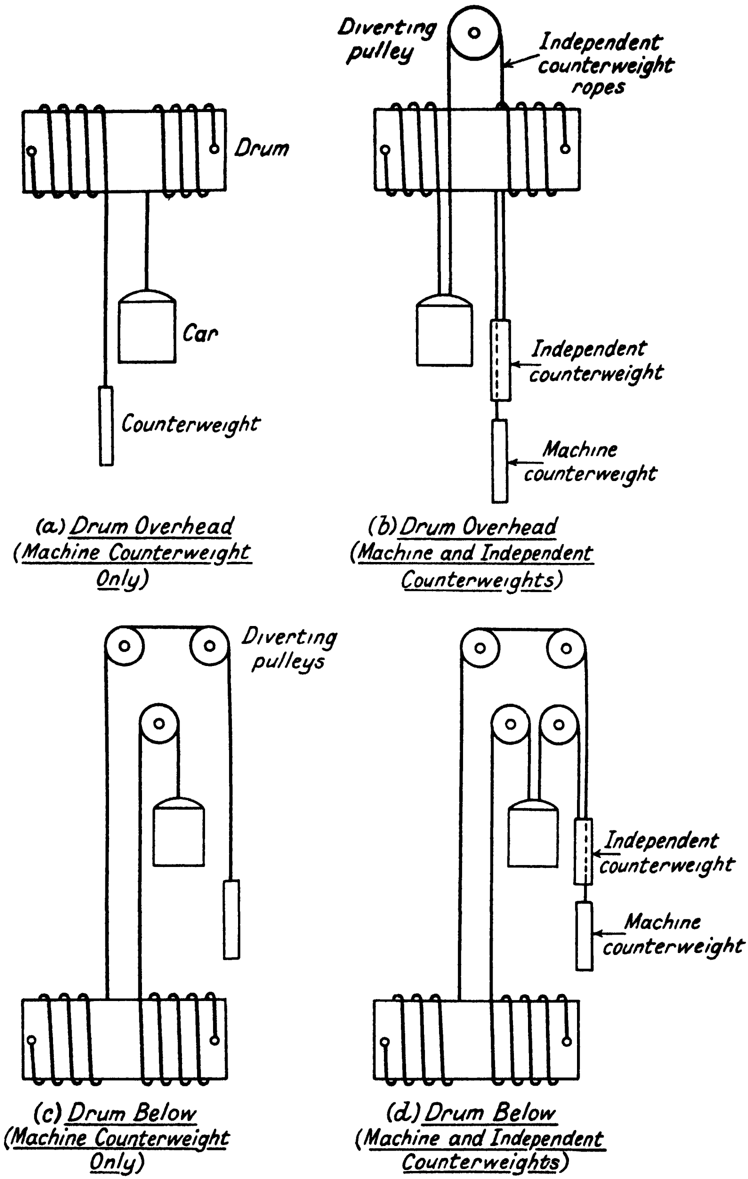



FIG. 41. SYSTEMS OF ROPING FOR DRUM DRIVE

the machine counterweight cables passing through the independent counterweight.

Fig. 41 (*c*) and (*d*) show the drum located in the basement, the former employing a machine counterweight only, and the latter both machine and independent counterweights.

**Compensating Ropes.** These are sometimes fitted on long travel lifts with the objects of making the load on the motor constant during a journey from one end of the well to the other and of eliminating the effect of the rope weight in reducing the traction at the ends of travel. When the car is at the bottom of the well, the load on the motor is increased by the weight of the lifting ropes, which may be appreciable with high rises. Several methods of rope compensation are in use, but probably the best of these is that illustrated in Fig. 42. Ropes, equal in size and number to the lifting ropes, are secured to the car and pass to the counterweight via a diverting pulley fixed in the well bottom.

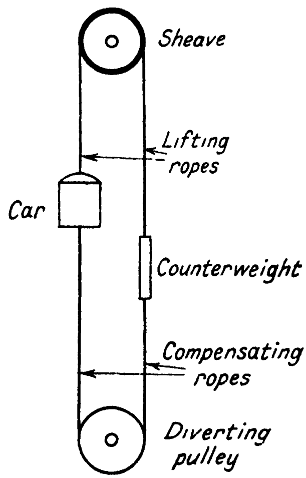



FIG. 42. COMPENSATING ROPES

## ROPES

**Material.** The lifting ropes employed on lifts are of stranded construction, each strand consisting of a number of steel wires. The steel used is either of special acid quality, termed Grade A, in which the phosphorus and sulphur contents are each not more than 0·04 per cent or acid quality, termed Grade B, in which the phosphorus and sulphur contents are each not more than 0·05 per cent. As an alternative, there has been a tendency in recent years to use wire drawn from basic steel made by the basic open-hearth process. Two grades of basic steel are available with similar limits for impurities to those quoted above for acid steel. Improvements in the technique of making basic steel and the fact that it can be made from home-mined ores are the reasons for extending its use to lift ropes. Great strength and flexibility are the most important properties of a

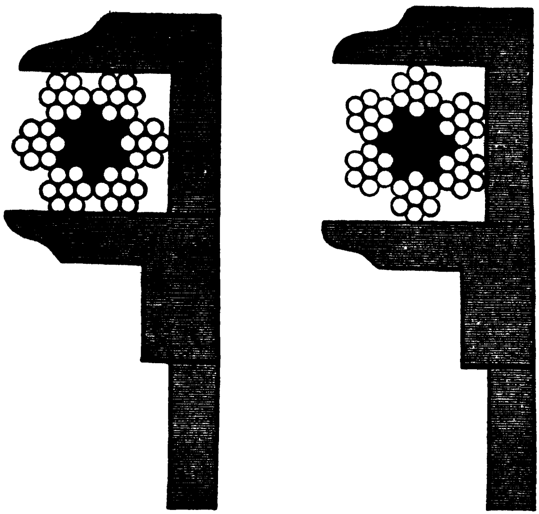
lift rope, the former being obtained by using a steel of high carbon content and the latter by using a stranded rope construction. The tensile strength of the steel used in the manufacture of the ropes described later is 70 to 80 or 80 to 90 tons per square inch. A higher tensile strength of 110 to 120 tons per square inch is sometimes used for the inner nine wires of Seale ropes, although the outer nine wires are of 70 to 80 tons per square inch. The high tensile strengths are obtained by using a steel of moderately high carbon content, cold working, by drawing the wires through a series of dies and, in addition, subjecting the steel to a heat treatment known as patenting. To obtain the best type of wire there must be a close adjustment of the carbon content and of the method of drawing.

The fibre cores of all lift ropes consist of jute, hemp, or manilla, impregnated with a special lubricant, the purpose of which is to act as a lubricating medium for the internal parts of the rope and to assist the rope when at work by reducing friction. Furthermore, the lubricant preserves the wires and cores from deterioration from the results of damp, especially when not in actual use. The lubricant must be free from acid, of a penetrating nature and not liable to harden or peel off. For traction drives it is necessary that the insides of the wires be lubricated, but the outside surface of the rope must be dry. This is difficult to achieve in practice, and a new rope usually needs several wipings with paraffin-soaked rag during its first few months of use in order to remove surplus lubricant squeezed out from the impregnated core.

**Sizes.** The size of the lift rope is usually denoted by the circumference of the circumscribed circle, although there is now a distinct trend in this country towards following the practice in America and many other countries of using the diameter instead of the circumference. Care is necessary in measuring the diameter, the correct and incorrect methods being shown in Fig. 43. The permissible variation in diameter is $-2$ per cent or $+5$ per cent. In measuring the diameter three values are taken at each of three places at least five feet apart, the average of these three measurements is the diameter of the rope.

**Lays.** Two methods are employed in laying the wires and strands of a lift rope, namely the *Albert* or *Lang's* lay and the

*Ordinary* or *Regular* lay. In a Lang's lay rope the strands are laid up to form the rope in the same direction as its wires were twisted to make the strand as in Fig. 44 (*a*). In the ordinary construction, however, the strand wires are twisted in one direction and the completed strands are laid up in the opposite direction to make the rope as illustrated in Fig. 44 (*b*). The



(*a*) (*b*)

FIG. 43. METHOD OF GAUGING WIRE ROPE

(*a*) Incorrect (*b*) Correct

(*British Ropes, Ltd.*)

advantage of Lang's lay rope is that it offers a bigger wearing surface when in use, and therefore can reasonably be expected to give a longer life than ordinary lay rope. Furthermore, a Lang's lay rope is more flexible than an ordinary lay rope. On the other hand, considerable experience is necessary in manipulating Lang's lay ropes as the tendency to kink and untwist is greater than with an ordinary lay. Hence, unless care is exercised in handling the rope, it may be incorrectly installed, with serious results to the length of service. In this country Lang's lay ropes are generally used, whilst in America the ordinary lay is very popular.

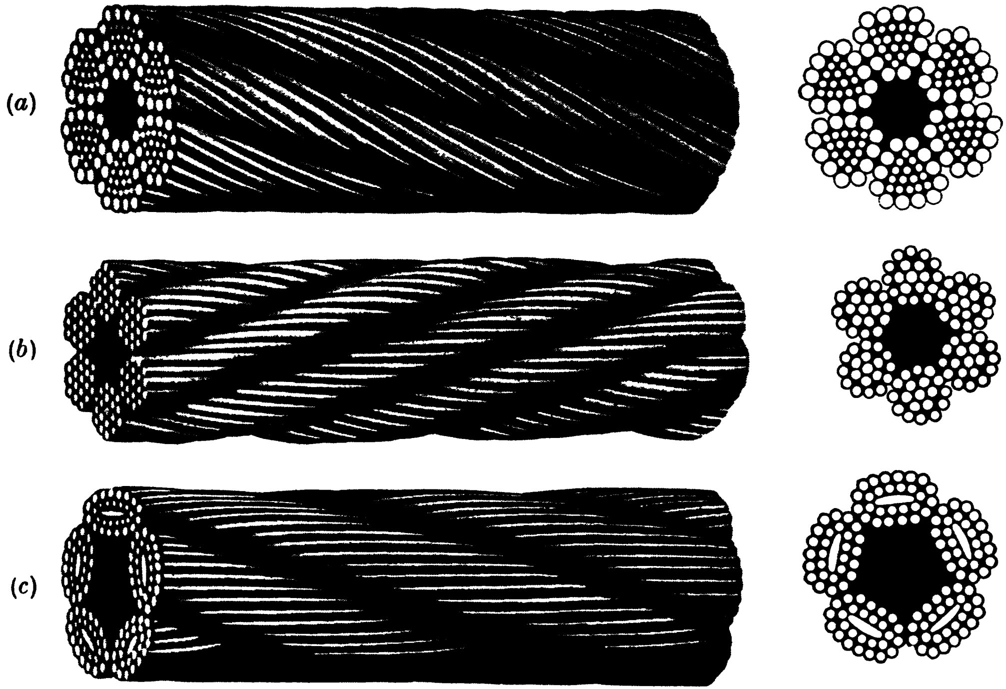



Fig. 44. Types of Rope Lays

(a) Lang's lay, right hand. (b) Ordinary lay, left hand. (c) Ordinary lay, right hand.
(*British Ropes, Ltd.*)

The rope is usually of right-hand lay, which means that it is laid up to the right, or clockwise direction when looking at the rope end. Some ropes, however, are of left-hand lay, these being wound in the anti-clockwise direction looking at the end. Therefore, in addition to specifying the rope lay, the direction must also be stated, e.g. "Lang's lay, right hand." Fig. 44 (*a*), (*b*), and (*c*) show right-hand Lang, left-hand ordinary, and right-hand ordinary lays respectively. In some sets of lift ropes, right- and left-hand ropes are used in an effort to produce a non-rotating combination. For example, if four lifting ropes are installed, two ropes would be of right-hand lay and the other two of left-hand lay.

The length of lay of a rope is the distance, parallel with the axis of the rope, in which a strand makes one complete turn about the axis of the rope. The lay of the strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand.

**Factor of Safety.** The minimum factor of safety of the combined lifting ropes should be 10, based on the contract load plus the weight of the car and the accessories. Although the above is usually specified and is termed the "Rope Factor of Safety," it does not give a true indication of the margin of safety because some allowance must also be made for the initial stresses in the wire during manufacture, the additional forces in the rope during acceleration and the bending stresses set up when the rope passes over the sheave and pulleys. With high car speeds acceleration is also higher and the acceleration stresses therefore greater. In order to allow for these stresses a greater Factor of Safety should be used with high car speeds than with low speeds. Whilst 10 is reasonable for car speeds up to 400 ft. per minute, a factor of 11 should be used for speeds between 400 and 600 ft. per minute, and a factor of 12 for speeds between 600 and 1 200 ft. per minute. With a traction drive, however, the number of ropes needed to obtain adequate traction may exceed the number required by simply applying the above Factor of Safety. For lifts which do not carry passengers, e.g. service lifts, a Factor of Safety of 8 is adequate.

**Round Strand Ropes.** The ropes generally employed for lift work are round stranded and usually have six or eight

strands. Some of the most popular rope constructions are described below.

(1) 6 × 19 (12/6/1). Each strand consists of nineteen wires laid with one layer of twelve wires round another layer of six wires round one central wire, all wires being of the same diameter. The six strands are laid round an impregnated core to form the rope.

(2) 6 × 19 (12/6/1) WITH SIX FILLER WIRES. This is similar to the 6 × 19 rope above, but has in addition six smaller filler wires laid in the interstices between the six-wire and twelve-wire layers. The object of these small wires is to fill the spaces between the two layers and so assist the rope to retain its shape. In assessing the rope strength these small filler wires are considered as not bearing any load.

(3) 6 × 19 (9/9/1) SEALE. Wires of different sizes are employed in this rope, each strand of nineteen wires being made up of an outer layer of nine large wires, then a layer of nine small wires and finally one central large wire. The six strands are laid round an impregnated core in the usual manner. This rope is stiffer than the 6 × 19 uniform rope and is therefore not as suitable as the uniform rope for small diameter sheaves or pulleys or when the drive has reverse bends in the roping system. Because of its equal lay and more solid rope construction, however, it is a better rope than Number 1 above, for general use on traction sheaves.

(4) 8 × 19 (12/6/1) WITH SIX FILLER WIRES. This is similar to Number 2 above, except that it has eight strands instead of six and is therefore a little more flexible but has less resistance to abrasion because of its smaller diameter wires. It is also not quite as strong as a 6 × 19 rope of similar diameter.

(5) 8 × 19 (9/9/1) SEALE. This is similar to the 6 × 19 Seale, but has eight strands instead of six and is thus more flexible than a 6 × 19.

Other round strand constructions less frequently employed for lifts than those above are as follows—

(6) 6 × 12 AND FIBRE. This has six strands each consisting of a single layer of twelve wires laid round a fibre core. The six strands are in turn laid up round a central fibre core. This is not suitable for traction drives as, in these circumstances, the rope does not retain its shape.

(7) 6 × 24. Each strand of this rope consists of twenty-four wires all of the same size laid in two layers, one of fifteen wires round another of nine wires round a fibre core. The six strands are laid around a central fibre core. Like No. 6 it is not used for traction machines.

(8) 6 × 37. This rope is similar to the 6 × 19 uniform rope Number 1, but has an additional outer layer of eighteen wires resulting in a particularly flexible rope. It is not suitable for traction drives because of the small diameter of the wires.

Another round stranded rope sometimes used in America is the "Warrington" construction which, like Seale ropes, uses wires of different sizes. The large wires resist abrasion, and the small ones have more resistance to bending fatigue. In the 6 × 19 Warrington rope three sizes of wires are employed. Each strand is formed of an outer layer of twelve wires which are alternately of large and small diameter, then a layer of six wires of medium diameter and, finally, a central medium diameter wire. The six strands are made up to form the rope in the usual manner. Like the Seale rope, the Warrington suffers from lack of flexibility. Some of these round rope sections are shown in Fig. 45.

The most popular ropes at the present time for high-speed traction lifts are Numbers 3 and 5 above, these having replaced Number 1 which, until recent years, was used to a large extent. Numbers 3 and 5 are generally used with undercut sheave grooves.

**Ropes of Special Strand Construction.** The British standard grades of steel used for lift ropes which have specially shaped strands are as follows—

| Grade of Steel | Breaking Strength (tons per in.$^2$) | Grade of Steel | Breaking Strength (tons per in.$^2$) |
|---|---|---|---|
| Best Patent Steel . | 80–90 | Best Plough . . . | 100–110 |
| Special Improved Patent . . | 90–100 | Special Improved Plough . | 110–120 |

The quality of the steel is the same as that for round strand ropes. The two standard constructions of these flattened strand ropes are known as 5/27, 28, or 29 *oval* and 6/25 *F*. The 5/27

oval (16/11/4) construction is the one generally adopted for lifts.

(1) 5/27, 5/28, OR 5/29 OVAL. This rope is made of five oval strands laid around an impregnated fibre core. Each strand

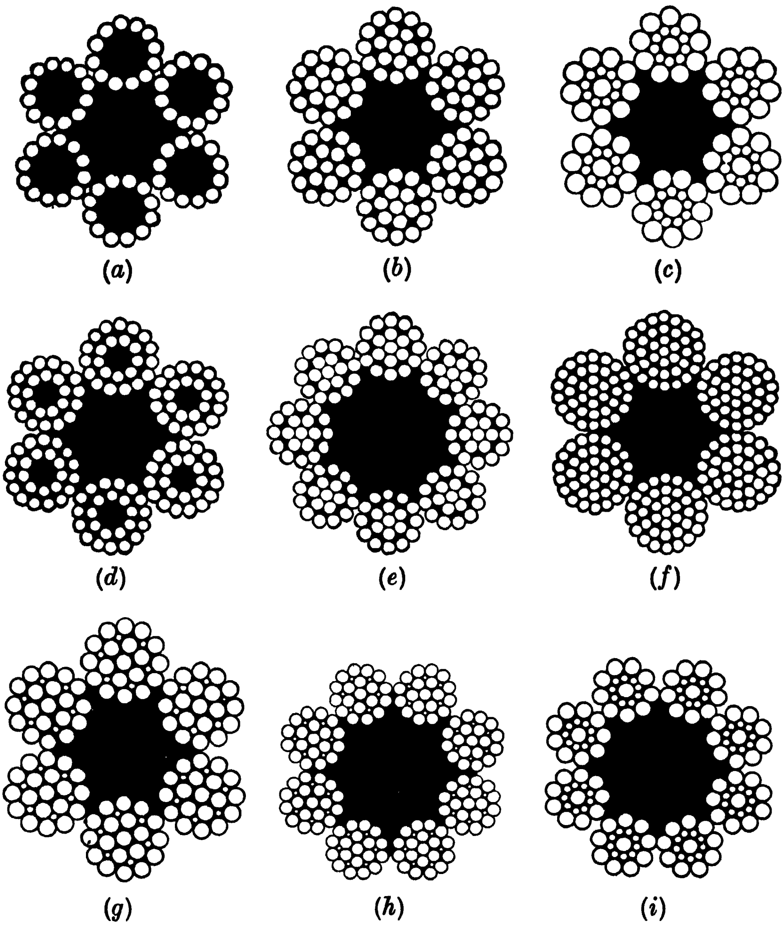



FIG. 45. ROUND STRAND ROPE SECTIONS

(a) 6 × 12 and fibre (b) 6 × 19 (c) 6 × 19 Seale (9/9/1)
(d) 6 × 24 (e) 8 × 19 (f) 6 × 37
(g) 6 × 19 with fillers (12/6/1) (h) 8 × 19 with fillers (12/6/1) (i) 8 × 19 Seale (9/9/1)

(*British Ropes, Ltd.*)

consists of twenty-seven, twenty-eight, or twenty-nine wires laid in two layers around a core consisting of a flat wire, an elliptical wire, or a flat strand of a number of round wires.

(2) 6/25 F. Six flattened strands are laid around an impregnated core to form this rope. The strand construction is twelve large wires laid around twelve smaller wires around a triangular shaped core which may consist of one or more shaped wires or one or more round wires.

The manufacture of flattened strand ropes was the logical development of the desire to produce a rope which, by reason of its power to resist abrasion, would give a longer life than did the round strand rope. It will be readily seen that with ropes of this type, frictional wear is spread over a greater number of the outer wires of the rope. In a round strand rope the wear is taken on one wire in each strand when the rope is new, and these wires are considerably reduced in sectional area before any appreciable wear is taken on the adjacent wires. In the flattened strand construction, owing to the friction being distributed over a greater external surface, the wear is much more even and the loss of sectional area of the vital outside wires much slower. Owing to the smooth surface and more nearly circular cross-section obtained with a flattened strand rope, the wear on sheaves and pulleys is reduced to a minimum. Flattened strand ropes show approximately 150 per cent more wearing surface than round strand ropes. Despite this, the amount of these special strand ropes in use on lifts is not nearly so great as that of round strand ropes. Special strand rope sections are shown in Fig. 46.

**Preformed Ropes.** A special process known as *preforming* was introduced into this country from America about twenty years ago and is now incorporated in the manufacture of what are termed *preformed* ropes. In a rope of this type the strands are passed through a preforming head which gives to the wires the exact final shape which they will take up in the completed rope. In the manufacture of ordinary rope, the wires are held forcibly in position throughout the life of the rope, as can be seen by cutting such a rope at any point, when the strands and wires will immediately fly apart. Preforming the wires prevents this, as they all lie naturally in their true positions, free from internal stress. Lang's lay or ordinary lay ropes can

be preformed; such ropes are sold under various trade names, probably the best known being the "Bluestrand Tru-lay."

Although the initial cost of a preformed rope is greater than that of a corresponding rope of ordinary construction, the manufacturers claim that the many advantages of this rope far outweigh its extra cost. The advantages of this rope which

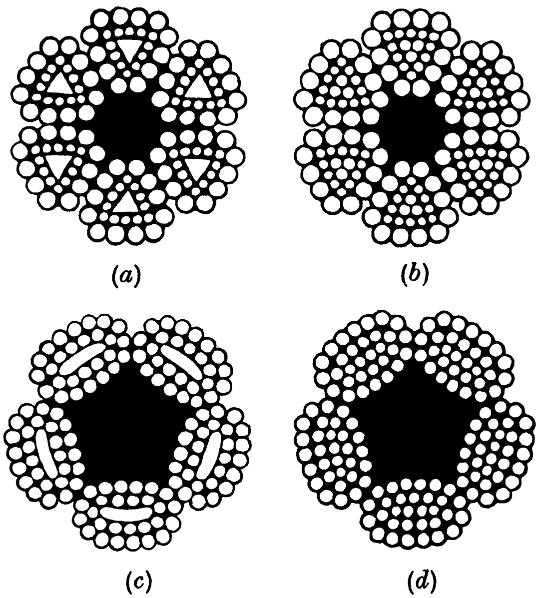



Fig. 46. Special Strand Rope Sections

(a) 6/25 F (12/12/triangle) (b) 6/25 F (12/12/3)
(c) 5/27 oval (16/11/oval) (d) 5/27 oval (16/11/4)

(*British Ropes, Ltd.*)

have been borne out by practical experience may be summarized as follows—

(i) The rope is completely "dead" due to the reduction of internal stresses.

(ii) It has longer life, due to the uniform distribution of, and the large reduction in, the internal stresses. This claim has been confirmed both by practical experience and by laboratory tests. Regarding the latter, the Third Report of the Institution of Mechanical Engineers Wire Ropes Research Committee

states that on pulleys of corresponding diameters, Tru-lay ropes are distinctly superior in 6 × 19 ordinary lay ropes, particularly under the severe conditions imposed by the use of small pulleys. In summarizing, the report states that Tru-lay ropes were superior to those made by the usual method of manufacture, particularly on small pulleys and in 6 × 7 construction (not a lift rope).

(iii) The load is evenly balanced on individual strands and wires.

(iv) There is no tendency to high strand even under the severest conditions.

(v) When the outer wires break from long wear there is no tendency for them to fray out from the body of the rope, but they continue to lie in their proper places. This prevents damage to adjacent wires and to sheaves and pulleys.

(vi) It is more easily spliced as there is no need to seize the strands.

(vii) There is less tendency to "kink" than with ordinary ropes.

Preformed ropes are now being used in increasing numbers for lift work.

## ROPE FASTENINGS

No car or counterweight rope should be repaired or lengthened by splicing, continuous lengths being invariably employed. Several methods are used for terminating the ropes at the car and counterweight, the best and most generally adopted being by *spliced return loops*, *clipped return loops*, or individual *tapered babbited sockets*. Loops must not bear directly on their fixings but must be lined with proper thimbles. In all cases the fastenings should be capable of sustaining a load of not less than 80 per cent of the ultimate strength of the undisturbed rope.

**Spliced Ends.** Splicing forms a satisfactory method of terminating a rope end, but care is necessary in forming the splice. and the work should be carried out by an expert, to secure the best results. The rope is passed round a thimble, and sufficient free end of the rope left to form a splice of adequate length; after which the core is cut out from the free end. The free strands are opened out and each strand threaded through those of the main rope according to a definite schedule. Special tools

FIG. 47. LIFT ROPE THIMBLE AND SPLICE
(*British Ropes, Ltd.*)

FIG. 48. CORRECT METHOD OF FITTING BULLDOG GRIPS
(*British Ropes, Ltd.*)

FIG. 49. BULLIVANT'S DOUBLE THROAT CLAMP
(*British Ropes, Ltd.*)

are used to facilitate the operations of opening out the main rope strands and inserting those of the free end. The splice should have at least three tucks with a whole strand of the rope and two tucks with one half of the wires cut out of each strand made, under and over, against the lay of the rope. When the splice has been made, any unevenness may be removed by carefully pounding with a wooden mallet, thus leaving a perfectly uniform exterior. Finally, the splice is carefully bound with either hemp or fine stranded wire as shown in Fig. 47. The lengths of satisfactory splices should be approximately as follows—

| Circumference of Rope (in.) | Length of Splice (in.) | Circumference of Rope (in.) | Length of Splice (in.) |
|---|---|---|---|
| 1 | 7 | 2½ | 19 |
| 1¼ | 9 | 2¾ | 21 |
| 1½ | 11 | 3 | 24 |
| 1¾ | 13 | 3¼ | 27 |
| 2 | 15 | 3½ | 30 |
| 2¼ | 17 | | |

**Bulldog Clips.** Clips form an effective method of fastening rope ends provided they are of good design, of the proper size, and are correctly fitted. They have an advantage over other methods of fixing in that the rope can be more readily adjusted to take up stretch. The correct method of fixing these clips is shown in Fig. 48. For ropes up to 3 in. circumference at least three clips per rope end are recommended, for ropes over 3 in. and up to 4 in. in circumference four clips should be used, and for ropes over 4 in. in circumference five clips per end. After the clips have been fitted it is advisable, the following day, again to tighten up the nuts, as it is often found this is necessary owing to the rope squeezing down.

The clips must always be fitted so that the castings are on the loaded rope, or in other words, the U-bolts must always be on the short end of the rope.

An improved form of clip known as "Bullivant's Double Throat Clamp" is shown in Fig. 49. This clip is claimed to be more effective than the ordinary bulldog pattern as it prevents the crushing of the rope which occurs when the ordinary clamps are used.

**Sockets.** When properly made, the white-metal and socket method of rope capping is probably the strongest known, but great care must be taken to see that the proper alloy is used at the right temperature, and that the wires are perfectly clean and free from grease. An open tapered socket is shown in Fig. 50. Several methods are employed for fitting the sockets, one of the best of which is as follows—

The end of the rope to be socketed should be bound with soft iron wire for at least one inch more than the length of the chamber, and again above this length for a further six or eight inches. After placing the socket on the rope, the first binding should be removed, the rope end unlaid, and each individual wire straightened out so that the group of wires resembles a brush. Each wire should then be turned over to form hooks, facing inwards to the centre of the rope, and the fibre centre cut out. Each wire must be properly cleaned, preferably with petrol, which quickly takes away any grease or dirt and leaves the wires dry. After this the wires should be roughened with emery cloth. When all the wires have been cleaned they are drawn into position in the socket. The socket is then slightly heated to prevent the too rapid chilling of the white metal, thus ensuring its penetration. After this the socket is fixed in a vice and asbestos yarn or clay wrapped round the rope, under the socket, so as to plug the mouth of the socket and prevent the metal running through. The socket should be at a temperature of about 212°F. immediately before the molten metal is poured in. Some powdered resin should then be dusted amongst the wires. The metal used must have a low melting point so as not to anneal or take the temper out of the wire and, further, must have practically no contraction and set very hard. The melting point should be below 750°F. and excess heat must not be applied to the metal, otherwise the temper of the wires will be damaged. The correct temperature is readily indicated by inserting a chip of soft dry wood, e.g. a match stick, which slightly chars when the metal is ready for use. The proper temperature for pouring is between 635°F. and 685°F. After running in the white-metal, it should be allowed to cool naturally, after which it will be found that the cone has been formed throughout the whole length of the barrel.

**Rope Equalizing Gear.** Some means are usually provided

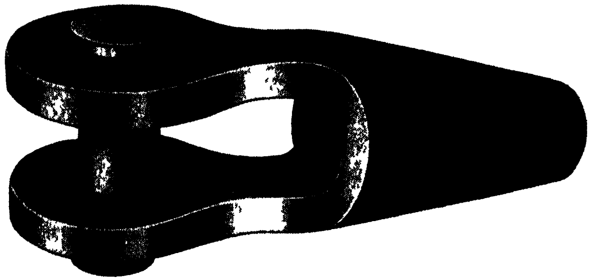


**Fig. 50. Open Tapered Socket**
*(British Ropes, Ltd.)*

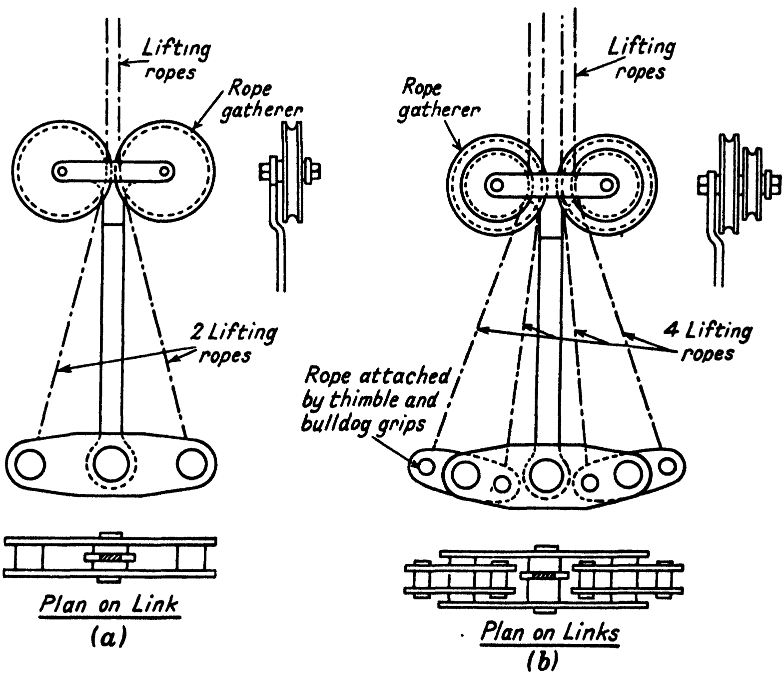



**Fig. 51. Rope Equalizing Gear**
(*a*) With two ropes (*b*) With four ropes

on lift ropes to equalize the load on the individual suspension ropes. Several different forms of equalizing gear are in use, but the principle of the simplest and probably most widely used is shown in Fig. 51 (*a*) and (*b*). With two ropes, each rope passes over a guide pulley or rope gatherer and the ends are attached, one at each side of a lever. This lever is free to rotate and takes up a position inclined to the horizontal, as one rope stretches more than the other. Thus each rope is subjected to the same tension. Three levers and four pulleys are used for a four-rope system as in Fig. 51 (*b*), the principle of operation being similar to that for two ropes.

# CHAPTER V

## MOTORS

**General.** Several different types of motor suitable for lift work are available, the particular motor chosen depending upon the supply characteristics, car speed, and quality of service to be provided. For many purposes an ordinary commercial motor of speed between 750 r.p.m. and 1 200 r.p.m., and having certain special features, is suitable. Speeds of between 600 r.p.m. and 900 r.p.m. are usually preferred, whilst at speeds above 1 000 r.p.m. there is difficulty in obtaining the necessary degree of silence, even if special precautions are taken in the design of the motor room and the mechanical equipment. Furthermore, the higher the speed the greater the kinetic energy and the more powerful the braking effort required, but on the other hand the price decreases as the speed increases. The graphs in Fig. 52 give some idea how the kinetic energy and price vary with the motor speed.

The main requirements of a lift motor are, a starting torque equal to at least twice the full load torque, quietness, and low kinetic energy; the last feature is necessary to obtain rapid acceleration and deceleration, together with a minimum amount of brake lining wear. In addition, the armature or rotor shaft must be capable of withstanding the high stresses due to braking and should be extended at the free end and made square, in order that the lift may be operated by hand, with a crank handle, in emergency and for effecting adjustments. The motor will be required to run in the same direction, either as a motor or as a generator, it being noted that when the load is a hoisting one, e.g. full load up, the machine functions as a motor, and when the load is overhauling, e.g. empty car up, the machine operates as a generator.

**Size.** The theoretical horse-power of the motor required to drive any lift is calculated as follows—

Assume that the maximum car load is 10 cwt., the maximum

speed 250 ft. per min., and that the counterweight is equal to the car plus 50 per cent maximum load—

The out-of-balance load = 5 cwt.

$$\text{i.e. h.p.} = \frac{5 \times 112 \times 250}{33\,000} = \underline{\underline{4{\cdot}25}}$$

In practice, the horse-power required for satisfactory service will be considerably more than the theoretical horse-power, the actual amount depending upon the overall mechanical

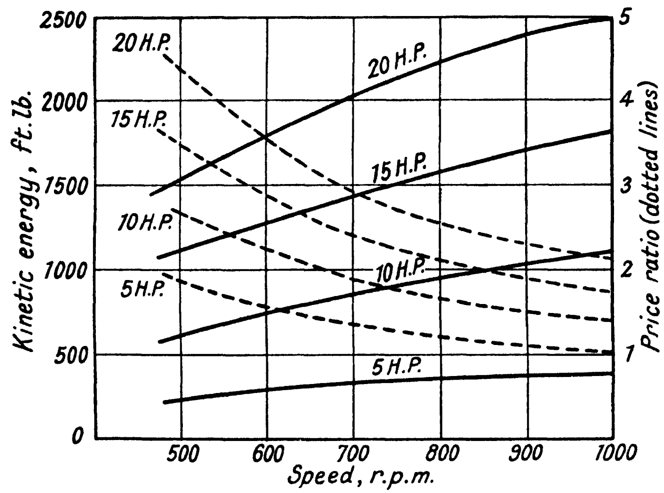



FIG. 52. GRAPHS SHOWING VARIATION IN PRICE AND KINETIC ENERGY WITH MOTOR SPEED
(*Metropolitan Vickers Gazette*)

efficiency of the lift, which may be anything between about 30 per cent and 60 per cent (this varying with the size of the lift and the drive employed). Suitable motor sizes for various car loads and lifting speeds are shown in Table (*a*) on p. 95.

The figures quoted in the table are applicable to lifts with low efficiency irreversible worm gearing, and with the counterweight balanced for half the maximum car load.

In modern lifts various methods are employed to improve the overall mechanical efficiency. High-efficiency worm and worm-wheel gearing is used, and for the sheave shaft tapered

roller bearings are sometimes employed. Care is also taken to suspend the car from a point above its centre of gravity instead of from the geometrical centre of the crosshead and so reduce the side thrust on the guide shoes. Roller guide shoes still further increase the mechanical efficiency. The adoption of

(*a*) H.P. OF MOTORS FOR LOW-EFFICIENCY GEARED LIFTS

| Car Speed (ft. per min.) | Contract Load (cwt.) | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 | 40 |
| 50 . . . | 2 | 3·5 | 5 | 6 | 8·5 | 11·5 |
| 100 . . . | 3 | 5·5 | 8 | 10 | 15 | 20 |
| 150 . . . | 4 | 8 | 11 | 15 | 21 | 28 |
| 200 . . . | 5 | 10 | 14 | 18 | 27 | 37 |
| 250 . . . | 6 | 12 | 17 | 23 | 34 | 45 |
| 300 . . . | 7 | 14 | 21 | 27 | 40 | 54 |

such measures may result in mechanical efficiencies of geared machines as high as 65 per cent, or 70 per cent for gearless machines. When such steps are taken, the overall efficiency of a geared machine may be as high as 60 per cent and the horse-power of the motors required would then be about two-thirds of those shown in Table (*a*). Suitable motor sizes for modern lifts with high efficiency gearing are shown in Table (*b*).

## DIRECT CURRENT MOTORS

**Motors for Car Speeds up to about 100 ft. per min.** A single-speed shunt or compound wound motor is employed for these low speeds, the larger sizes being equipped with commutating poles to give sparkless commutation in both directions of rotation. With car switch control, however, single-speed motors are sometimes used for car speeds up to 150 ft. per min. As previously mentioned, the machine must be capable of running as a generator or a motor, and this entails special arrangements being made in the case of a compound motor. The diagrams in

Fig. 53 show the directions of the currents in the windings of a compound wound motor when "motoring" and "generating." When operating as a motor, both fields are in the same direction, but on change over to a generator, the back e.m.f. becomes greater than the applied voltage, and the two fields oppose

(*b*) H.P. OF LIFT MOTORS FOR MODERN HIGH-EFFICIENCY GEARED LIFTS

| Contract Load | | Car Speed in ft. per min. | | | | |
|---|---|---|---|---|---|---|
| | | 50 | 100 | 150 | 200 | 300 |
| Goods Car Load in cwt. | 5 | 1·25 | 3·5 | | | |
| | 10 | 2 0 | 4·5 | 6·0 | 8·0 | |
| | 15 | 3 0 | 6·0 | 8·0 | 10·5 | |
| | 20 | 4 5 | 8·0 | 10·5 | 14·0 | |
| | 30 | 6 0 | 10·5 | 14·0 | 20·0 | |
| | 40 | 8·0 | 14·0 | 20·0 | 25·0 | |
| | 60 | 10·5 | 20·0 | 30·0 | | |
| Passenger Car Load in lb. | 600 | | 3·5 | | | |
| | 900 | | 3 5 | 6·0 | | |
| | 1 200 | | 4·5 | 8·0 | 7·5 | |
| | 1 500 | | 6·0 | 8·0 | 10·0 | 12·5 |
| | 2 000 | | | 10·5 | 12·5 | 15·0 |
| | 2 500 | | | 12·5 | 15 0 | 20·0 |

each other. This results in a weakened field, reduced dynamic braking power, and an increase in the car speed. It is therefore necessary to arrange that the controller cuts out the series winding when the full speed has been reached, the object of the series winding being to provide a high starting torque.

When the main contactor closes, the brake shoes are released and the shunt field is energized via the starting resistances. Two methods are employed to cut out the starting resistances

and thus obtain acceleration. In the first method, an oil dashpot or a mechanical time relay is used to control the movement of the accelerating magnet plunger, and by this means the steps of starting resistance are cut out on a definite time basis, determined by the dashpot or relay adjustment. With the second method the accelerating switch coil is connected across the motor armature and the cutting out of the starting resistances is thus dependent upon the motor speed. At the instant of closing the armature circuit, the voltage across the armature

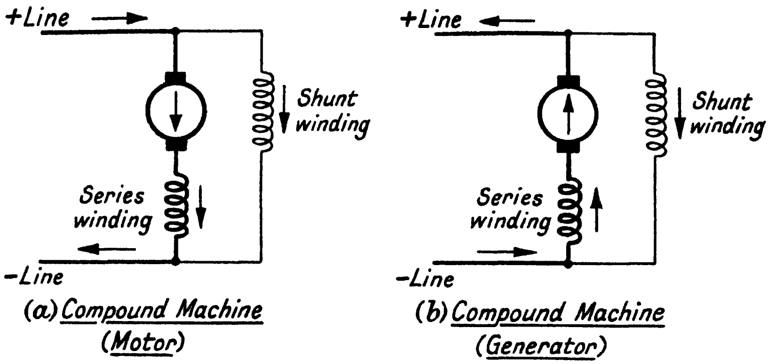



FIG. 53. CURRENTS IN WINDINGS OF A COMPOUND WOUND MACHINE

is small, but as the motor speed rises the armature voltage increases. Hence, the voltage across the accelerating magnet coil gradually increases and its contact arm cuts out the starting resistance at a rate proportionate to the increase in motor speed. The series field is cut out of circuit immediately the starting resistance has all been cut out.

Deceleration is obtained by re-inserting the starting resistance and by connecting a diverter resistance across the armature, thus producing a slow levelling speed, not subject to such wide variations in speed as with a series resistance. Immediately the main contactor opens, a braking resistance is placed in parallel with the armature. By this means the kinetic energy of the lift is converted to heat, which is dissipated in the resistance, and the resulting dynamic braking assists the mechanical braking action. The effect of the dynamic braking resistance across the armature is shown in Fig. 54. In (*a*),

which shows the normal running conditions, the back e.m.f. $E_b$ is in the opposite direction to that of the main voltage and the armature current $I_a$. When the power is cut off, the conditions are as shown in (b), the field current $I_f$, which is almost equal to the normal value, being maintained by the armature back e.m.f. The addition of the braking resistance gives the conditions shown in (c), the reversed armature current causing a reverse braking torque, the value of which depends upon the magnitude of the parallel resistance. Hence the rate of de-

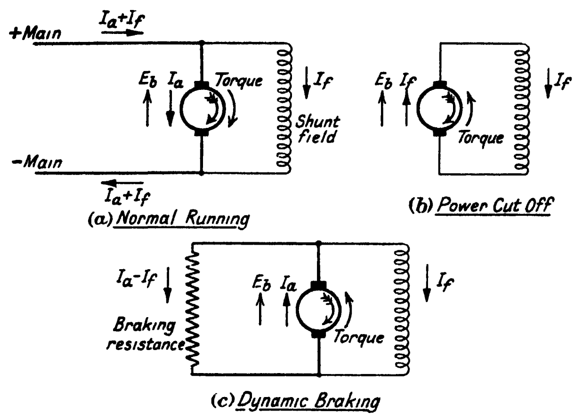



FIG. 54. DYNAMIC BRAKING WITH D.C. MOTOR

celeration caused by dynamic braking may be low or high, depending upon whether a high or low value of resistance is employed.

Motors of about 15 h.p. and over are sometimes provided with an additional shunt field in parallel with the main shunt field, the auxiliary field being automatically cut out as the speed rises, and re-inserted during the slowing down period. This auxiliary field increases the starting torque and improves the speed regulation.

**Motors for Car Speeds between about 100 ft. per min. and 250 ft. per min.** Two-speed motors, having speed ratios of 2–1, 3–1, or 4–1, are used in order to obtain a slow speed for efficient landing. The motor is similar to that used for single-speed working except that it is arranged for shunt regulation.

In a typical two-speed motor having speeds of 400 r.p.m. and 800 r.p.m., acceleration from zero is obtained by cutting out the series starting resistance, as for a single-speed motor. The field is at full strength (all resistance out) whilst running up to 400 r.p.m. Increase from 400 to 800 r.p.m. is obtained entirely by shunt field weakening, effected by inserting field resistance. Deceleration from 800 to 400 r.p.m. is obtained by short-circuiting the field resistance, and below 400 r.p.m. by introducing the series starting resistance and shunting the armature by means of a diverter resistance, as for a single-speed motor. Dynamic braking is also resorted to, prior to the application of the mechanical brake.

**Motors for Car Speeds of 300 ft. per min. and over.** During recent years there has been a demand for car speeds above 300 ft. per min., due to the withdrawal of certain building restrictions, and the consequent erection of higher buildings. In this country the maximum car speed at present is about 600 ft. per min., whilst in America speeds up to 1 400 ft. per min. are employed in the "skyscrapers," whose heights in some cases exceed 1 000 feet. With these high speeds it has been possible to make use of a specially designed slow-speed d.c. motor, the shaft of which is coupled directly to the driving sheave, without the use of gearing. This reduction in motor speed and elimination of gearing results in a smaller kinetic energy of moving parts. The motor, brake, and sheave are mounted on a common bedplate to form a single unit, and it is thus seen that the motor bearings carry the load of the car, counterweight, and the pull due to the ropes around the idle pulley (if a double-wrap drive) in addition to the weight of the motor armature, sheave, and brake drum. The motor is a shunt wound machine having a speed of between 50 r.p.m. and 120 r.p.m., depending on the duty, and is not usually equipped with commutating poles, these being scarcely necessary at such low speeds. On account of its large size it is not practicable to provide a range of speed of more than 1·5 to 1 by field control. In the earlier gearless machines the speed was controlled rheostatically by means of a combination of series and parallel resistances as in the case of the ordinary d.c. motor, but the best and most modern method is the application of the variable voltage or Ward-Leonard principle (see Chapter VI). The

major part of the speed variation is accomplished by varying the voltage applied to the motor, the remaining small change being effected by field control.

Although the first cost of a gearless machine is considerably more than that of a geared machine, the gearless motor normally does not need replacement throughout the life of the lift

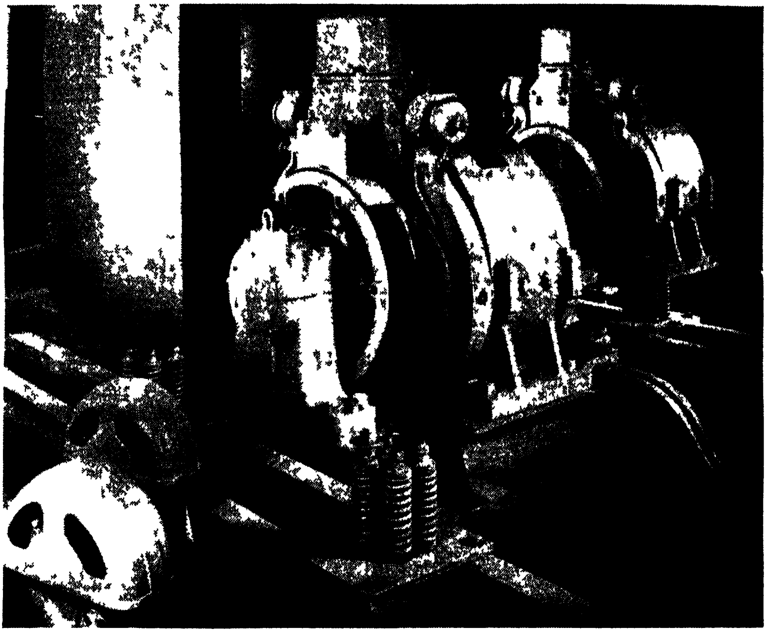


FIG 55 TWO GEARLESS MACHINES WITH 2 TO 1 ROPING, DOUBLE WRAP DRIVE
(*Express Lift Co Ltd*)

because of its low running speed. For the same reason the maintenance costs are low Because of the absence of gearing the efficiency is higher and hence the power consumption less. A better service can be obtained because of the higher acceleration, and the travelling is much smoother. Until recent years the gearless machine was seldom used for car speeds below 500 ft. per minute, but its superior performance over the geared machine has resulted in its employment for speeds as low as 350 ft. per minute.

Fig. 55 shows two gearless motors with brakes, sheaves and governors. These machines are part of an installation arranged with 2 to 1 double-wrap roping, interconnected signal collective control and contract loads and speeds of 2 500 lb. and 500 ft. per minute respectively.

A gearless motor complete with its brake and sheave is shown in Fig. 56, and a sectional view showing details of the

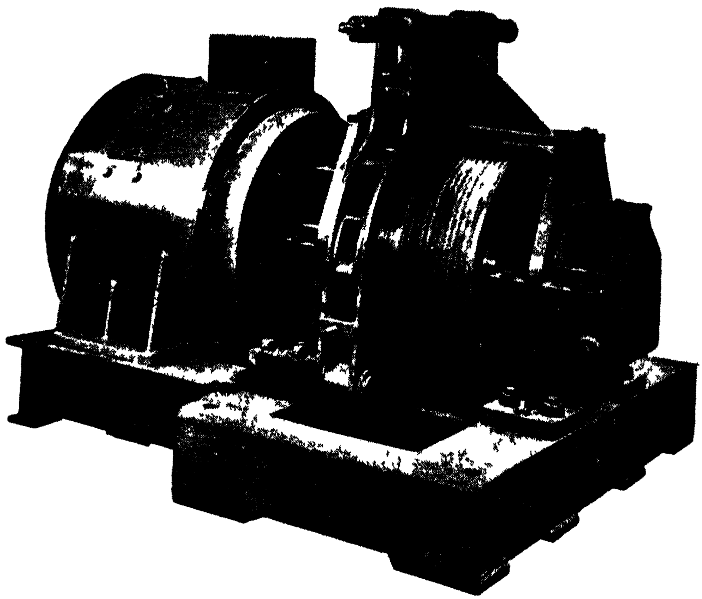


FIG. 56. GEARLESS MACHINE
(*B.T-H and J and E. Hall, L'd*)

motor construction is in Fig. 57. In this particular arrangement the motor armature is overhung outside the two main bearings on an extension of the shaft. Only the rope sheave and brake drum are mounted between the bearings. This design reduces the distance between the bearings, resulting in increased strength due to lower shaft stresses for the same amount of material. This arrangement has other advantages over the alternative method of mounting both electrical and mechanical

components between the two bearings. The mechanical portion, the size of which is determined mainly by the load and sheave reaction, can be standardized independently of the motor.

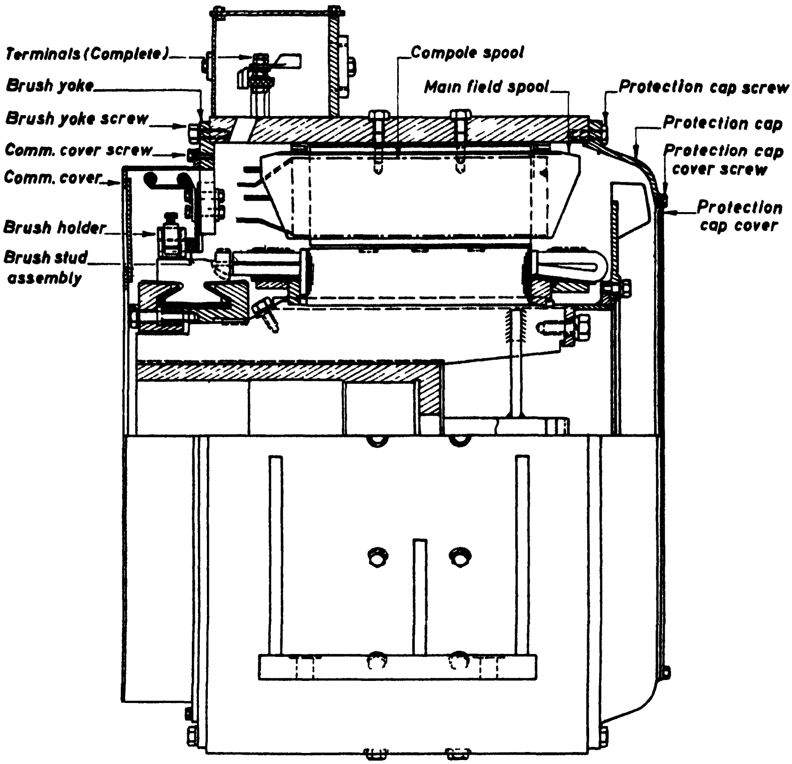



FIG. 57. SECTIONAL VIEW OF GEARLESS LIFT MOTOR
(*B.T.-H. Co.*)

The size of the motor is determined by torque and the duty cycle, so that, if necessary, more than one size of motor can be used with the same mechanical equipment. The motor can also be easily withdrawn for maintenance without disturbing the ropes.

## ALTERNATING CURRENT MOTORS

### Polyphase Supply

**Motors for Car Speeds up to about 100 ft. per min.** The single-speed squirrel-cage motor is suitable for these low speeds, although it suffers from the disadvantages of high starting current and a tendency to overheat if the duty is severe. The slip should be kept within reasonable limits to avoid too great a speed variation. It is necessary, also, that the motor should develop a high torque for starting and accelerating, but this means that it will inherently have a high slip, so that some

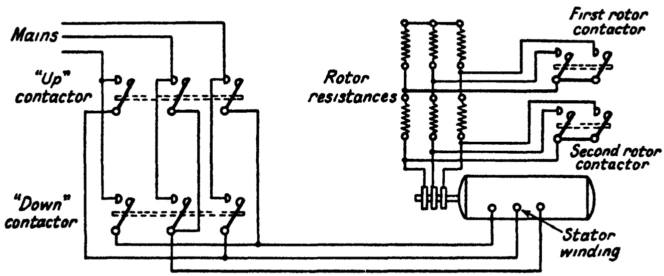



Fig. 58. Single-speed Slip-ring Motor with Two Steps of Rotor Resistance

compromise must be made in the design. Further, a low slip is obtained by reducing the rotor resistance, which is an indication that the starting current will be high. In practice, the starting K.V.A. should not exceed about 5 K.V.A. per h.p., the starting torque should be about 250 per cent full load torque and the slip at full load should not exceed 12 per cent. These motors are often switched directly across the lines, but it is frequently necessary to provide smoother acceleration by the use of starting resistances in the stator circuit. The short-circuiting of these resistances is controlled by an air or oil dashpot. The squirrel-cage motor is not suitable for duties exceeding 100 starts per hour.

Better speed regulation, lower starting current and smoother acceleration are obtained by using a wound rotor motor which is accelerated by cutting out the rotor resistances in one or more steps, these being controlled by dashpots. Although the

speed can be varied by rotor resistance, this machine is essentially single-speed, as the insertion of rotor resistance results in low efficiency and poor speed regulation. Hence, the rotor resistance is used for the short starting period only, when the loss in performance is unimportant. This type costs about 50 per cent more than the squirrel-cage motor but may be used for duties up to 120 starts per hour. For lift work this type of motor should have a starting K.V.A. not exceeding 3·25 K.V.A. per h.p., a starting torque not less than 225 per cent full load torque and the full load slip should not exceed 8 per cent. The connexions for a single-speed slip-ring motor with two steps of starting resistance are shown in Fig. 58.

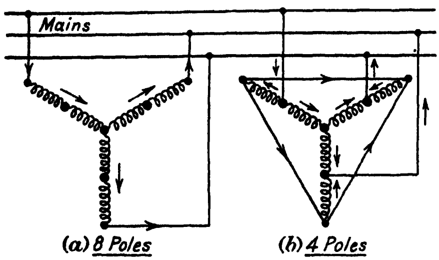



FIG. 59. STATOR WINDINGS OF TWO-SPEED SQUIRREL-CAGE MOTOR (Star—Two Parallel Star)

**Motors for Car Speeds between about 100 ft. per min. and 250 ft. per min.** For these car speeds it is necessary to employ one of the several available types of motor capable of running at more than one speed, in order to obtain a slow landing speed.

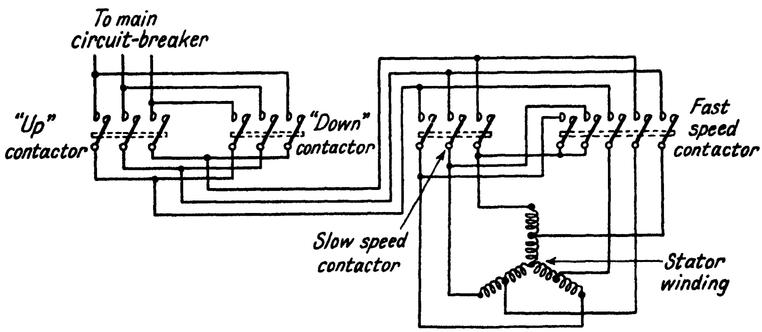



FIG. 60. TWO-SPEED SQUIRREL-CAGE MOTOR CONTROL CIRCUIT

SQUIRREL-CAGE INDUCTION MOTORS. The squirrel-cage induction motor can be adapted for pole changing by regrouping

the stator winding to give two polar combinations corresponding to the two speeds. For one combination of poles, the coils in any one phase give poles of similar polarity round the machine, the opposite poles being induced in the spaces between the coils. By reversing every alternate coil, the poles produced are alternately north and south and only half the original number of poles is produced. Pole changing can therefore only be used when the two speeds required are in the ratio of two to one. One method of obtaining half the number of poles, i.e. double the speed, by this reversal of current in half the winding, is shown in Fig. 59. The winding is connected in star for the larger number of poles, and in two parallel star windings for the smaller number of poles. For the direction of rotation to remain unchanged when the poles are changed, two of the phases must be reversed in relation to the line wires. The motor starting and running connexions are shown in Fig. 60. Another method, in which the windings are connected in delta for the larger number of poles, and in two parallel star circuits per phase for the smaller number of poles, is shown in Fig. 61. This is a better method, as an improved performance is obtained and no reversal of line wires and phases is necessary to maintain the same direction of rotation. A further disadvantage of pole changing is that, if the coil pitch is correct for one of the polar combinations, it is inefficient for the other.

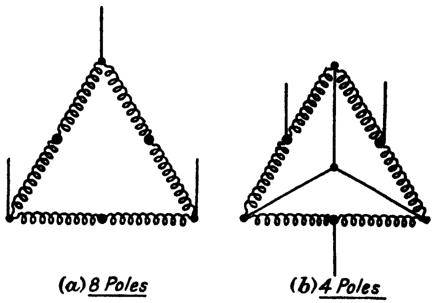



FIG. 61. STATOR WINDINGS OF TWO-SPEED SQUIRREL-CAGE MOTOR (Delta—Two Parallel Star)

In another form of two-speed squirrel-cage motor, two separate stator windings, wound in the same slots, are employed to give the pole change corresponding to the required two speeds. Ratios up to six to one are possible with this double wound motor, the high and low speed windings being cut in and out of circuit by means of a contactor. The disadvantage of this type is the complexity of the double winding and the difficulty of repair, especially if the damaged winding is the under one of the two.

These two-speed squirrel-cage motors are usually started up with resistance in the high-speed winding, whilst smooth deceleration is obtained by inserting a buffer resistance, either in the slow- or high-speed winding during transition to slow speed. The use of a choke instead of a buffer resistance results in a smoother and less peaked curve of braking torque. Typical curves for a 3 to 1 speed change double winding induction

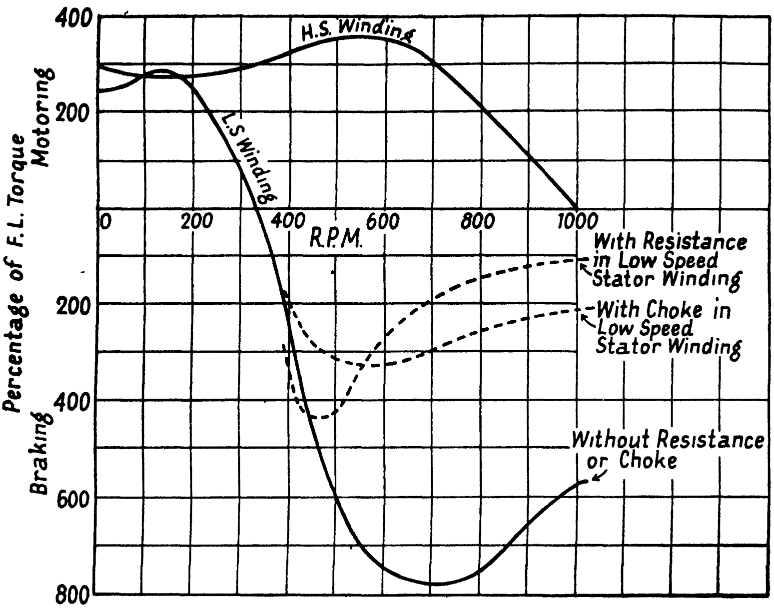



FIG. 62. TYPICAL SPEED/TORQUE CURVE OF 3 TO 1 POLE-CHANGE LIFT MOTOR
(*Bull Motors*)

motor are shown in Fig. 62. Another method of effecting smooth acceleration with lift motors of this type is to employ an induction regulator in the motor supply circuit; the regulator applying the starting voltage gradually to the high-speed winding without the use of resistances. The induction regulator is a transformer with a variable ratio of transformation, and is built like an induction motor, the stator forming the primary, and the wound rotor the secondary. The rotor is not free to rotate but its position can be altered through one pole pitch

by means of a small torque motor. This turning of the rotor varies the voltage applied to the high-speed winding, and results in very smooth acceleration.

SLIP-RING INDUCTION MOTORS. Speed changes, by the methods employed with squirrel-cage motors, may be obtained with a slip-ring motor, but this usually involves the use of two separate rotor windings arranged similarly to the stator windings. The rotor connexions must be changed at the same time as the stator connexions and this, together with the slip-rings, involves extra complications in the control circuit, although an improved performance is obtained. The use of two rotor windings may be avoided by carrying the rotor currents through internal short-circuited paths during one of the speeds, but this involves the loss of the slip-ring characteristics on one speed.

A method of producing two speeds with a wound rotor motor having only one rotor winding is described in the *Electrical Review* of 16th January, 1931. The rotor coils are grouped and pitched so that, although only one winding is employed, this reacts in a field having either of two polarities. This regrouping is possible for speed ratios of three to one and four to one, corresponding to 6/18 pole and 6/24 pole rotors, and for other ratios likely to be required in practice. The motor is started on the high-speed winding with rotor resistance in the usual manner, and slowed down by external resistance, which controls the rate of deceleration.

TANDEM MOTORS. The Tandem, two-speed a.c. motor, which has been employed on a number of lifts, consists of a wound rotor and a squirrel-cage rotor, forming the high- and low-speed sections respectively. These are assembled on the same shaft and the two frames bolted together to form a single two-bearing unit. Various speed ratios are obtainable and in a typical motor having a six-to-one ratio the speed obtainable from the wound rotor portion is 960 r.p.m. whilst the low speed from the squirrel-cage end is 160 r.p.m. In this particular motor, the slip-ring section is wound for 6 poles, and the squirrel-cage section for 36 poles. Approximate performance curves for the sections of this motor are shown in Fig. 63, from which it will be seen that if the lifting speed is at its maximum, this can be reduced to one-sixth, by transferring the supply from the slip-ring section to the squirrel-cage section.

Both sections are magnetically and electrically independent internally and each is capable of producing twice the full load torque, for starting purposes. The slip-ring portion is of standard design for lift service, whilst the low-speed end should have low slip and high starting torque to ensure a constant speed at all loads. A rotor of the motor is shown in Fig. 64 in

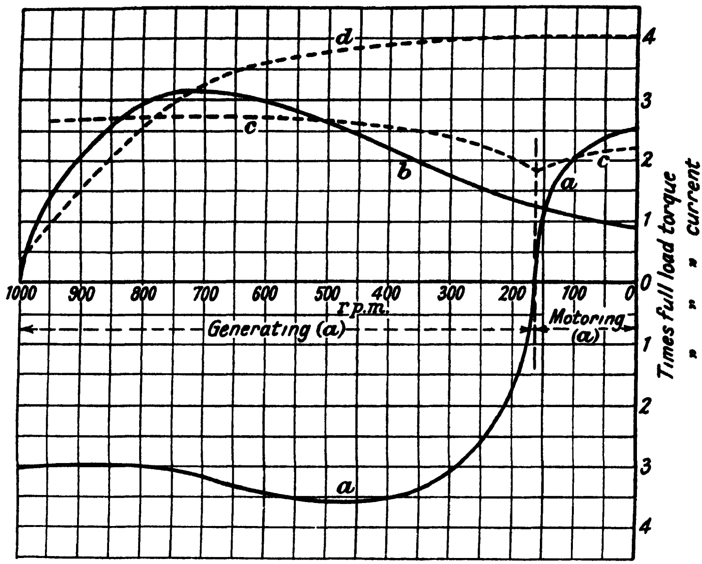



FIG. 63. CHARACTERISTIC CURVES OF THE TWO WINDINGS OF TANDEM MOTOR

(a) Torque of S C motor
(b) Torque of S R motor with no rotor resistances
(c) Current of S C motor
(d) Current of S R motor with no rotor resistances

*(Metropolitan Vickers Gazette)*

which the squirrel cage section is of special construction. This consists of alternate segments of steel and copper secured by steel end rings of inverted "L" sections, the segments being brazed to the steel end rings and the latter welded to the steel hubs. This construction results in a flat speed torque characteristic during deceleration.

It is usual to start up on the high-speed winding with resistance in the rotor circuit, the resistance being gradually

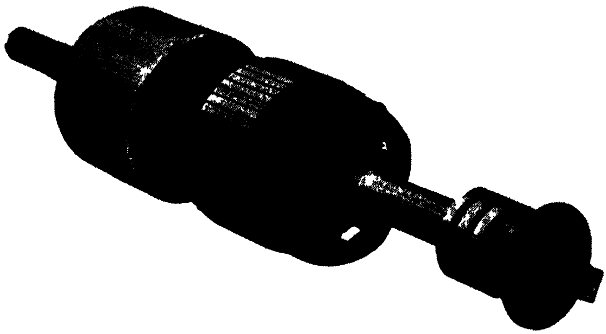


FIG. 64. THE ROTOR OF A TANDEM LIFT MOTOR
(*Bull Motors*)

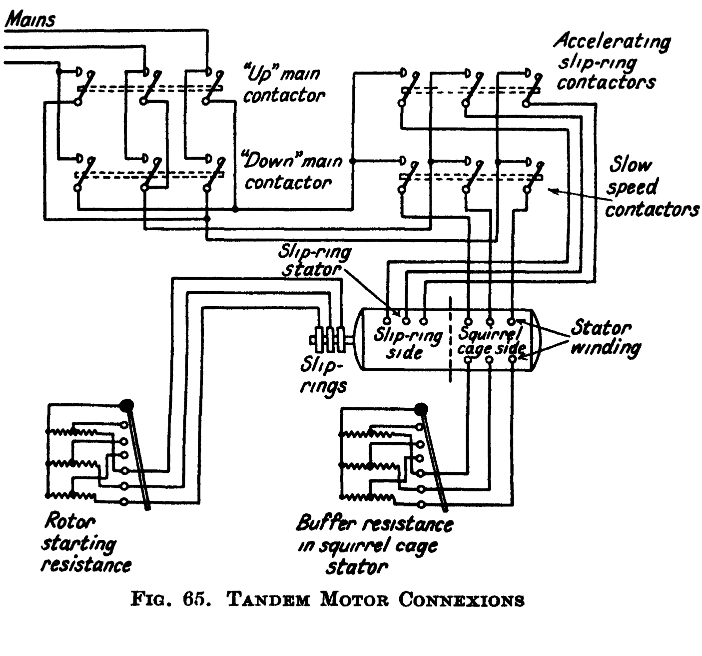



FIG. 65. TANDEM MOTOR CONNEXIONS

cut out until final running speed is attained. To change from high to low speed, a switch disconnects the high-speed winding and another switch energizes the low-speed section. On change over to low speed, dynamic braking occurs, and from the characteristic curves it will be seen that a reverse torque, up to approximately four times full load torque, is obtained. The inertia of the rotating parts helps to smooth out the change, but it is also necessary to insert a buffer resistance or a choke coil in the star point of the squirrel-cage stator winding to prevent the deceleration from being excessive. The resistance is gradually cut out during deceleration, leaving the slow-speed winding fully energized. The starting and running connexions for this type of motor are shown in Fig. 65.

The control of the Bull Super Tandem incorporates some patented features which make its characteristics different from the normal type described above. On changeover to the low speed section the high speed stator is not disconnected from the supply but is kept in circuit with the low speed stator whilst a resistance is inserted in the slip-ring rotor. The wiring for the two sections and the necessary resistances are shown in Fig. 66, and the speed torque curves for a 6 : 1 speed ratio in Fig. 67. The high speed accelerating resistance is between contactors 3 and 2, but in practice this consists of more than the simple one step shown in the diagram. During acceleration contactor 3 is closed and the various steps between 3 and 2 gradually cut out until finally No. 2 is closed and the motor is running at high speed. Contactor No. 3 opens after the closure of No. 2. The high speed section is thus running at contract speed without any rotor resistance and the squirrel-cage section is disconnected from the line by contactor No. 1. Slowing to the final levelling speed is performed by the contactors operating in the sequence shown in Fig. 67, which removes the levelling resistance step by step from the low speed stator and inserts it in the high speed rotor. The transition from the high speed (curve 1) to the low speed (curve 6) is thus effected smoothly.

Curves *A* and *B* illustrate the speed torque characteristics of the low speed and high speed sections acting separately. Curve 6 is the summation of these two and is the torque at the motor shaft during low speed. The torque contributed by the

high speed section is additive to that of the low speed section when motoring whilst it does not seriously reduce the net braking torque. The static torque at low speed must, of course, be at least 200 per cent full load torque as the lift may be called upon to re-level. In the arrangement described this

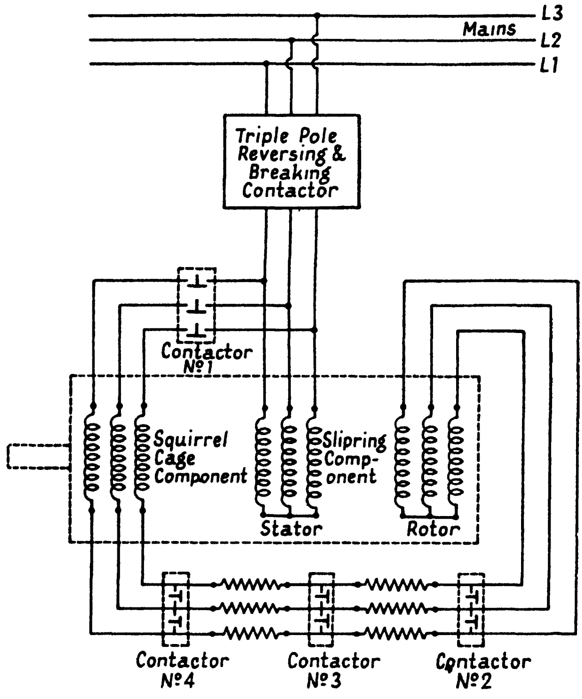



FIG. 66. BULL SUPER TANDEM LIFT EQUIPMENT
(*Bull Motors*)

requirement can be fulfilled and the low speed section kept to the minimum size since it has to provide only about 140 per cent full load torque, the remaining 60 per cent being supplied by the high speed section. A small reduction of the slip-ring rotor resistance will increase the low speed static torque without appreciably affecting the braking characteristics. Another advantage of this method of control is that the full load slip at levelling speed (less than 6 per cent) is somewhat lower than

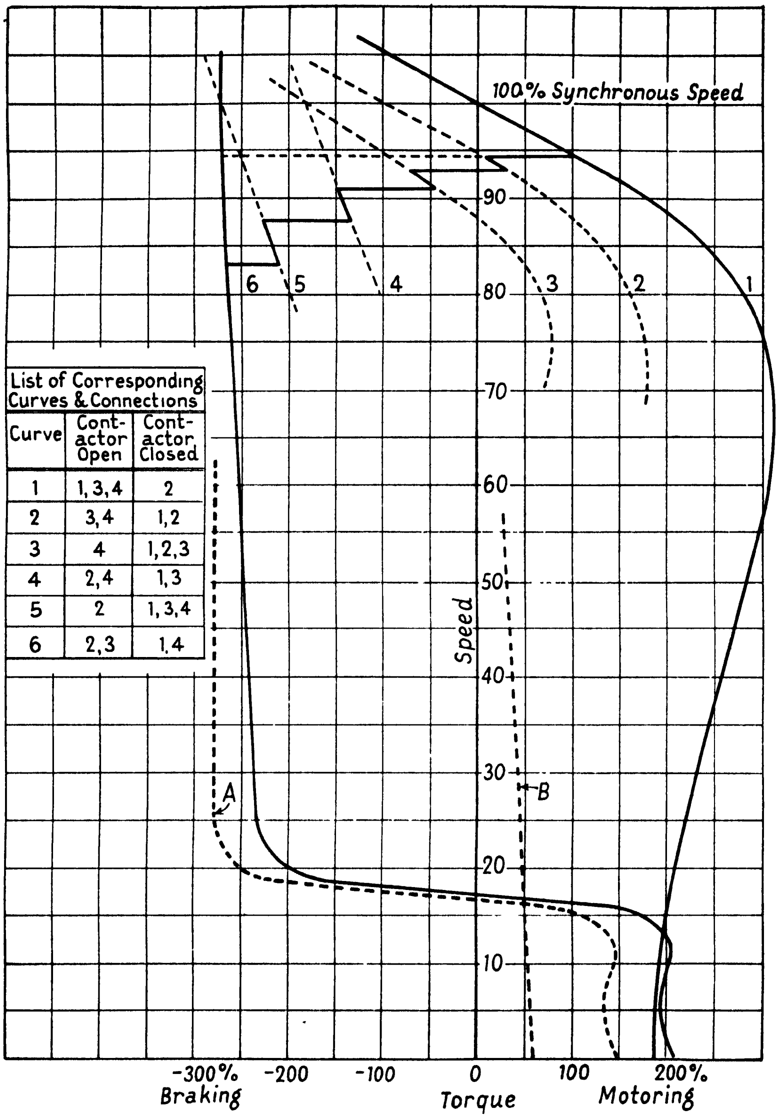



Fig. 67. Levelling Characteristics of Bull Super Tandem Lift Equipment Connected as Shown in Fig. 66

would otherwise be the case and this results in a smaller variation of speed with varying load.

The price of a tandem motor is nearly double that of the two-speed squirrel-cage motor (this ratio depends on the h.p.), but it has a higher efficiency and can be used for heavier duties.

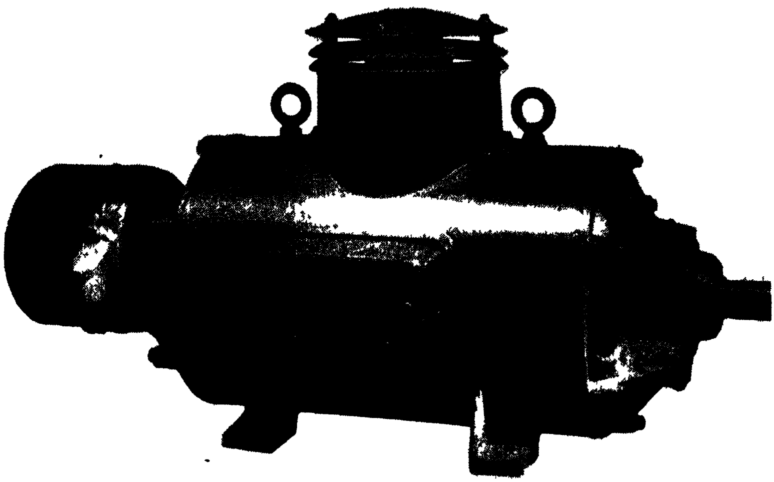


FIG. 68. HEAVY DUTY TANDEM MOTOR
(*Bull Motors*)

The approximate lift ratings of tandem motors of sizes 10, 20 and 30 h.p. are 140, 120 and 100 starts per hour.

For very frequent starts and stops a heavy duty type of the Bull Super Tandem is available. This consists of the standard motor with a built-in independently running fan unit which provides additional continuous ventilation. Fig. 68 shows this heavy duty tandem, the standard machine being similar except that the fan housing is not fitted. The ventilating unit consists of a fractional h.p. vertical spindle motor driving a propeller fan so arranged that it assists the paddle fan in the introduction of air to the interior of the machine. The paddle fan fitted to the standard and heavy duty machines is located in the centre between the two rotor components. Approximate

lift ratings for this heavy duty model are 240, 220 and 180 starts per hour for sizes of 10, 20 and 30 h.p. respectively.

A.C. COMMUTATOR MOTORS. Motors of the variable speed, shunt commutator type were popular for lift work, and speed changes of seven to one may be obtained in the smaller sizes, whilst changes as high as fifteen to one are possible in the larger sizes. The arrangement of the windings differs from that of the

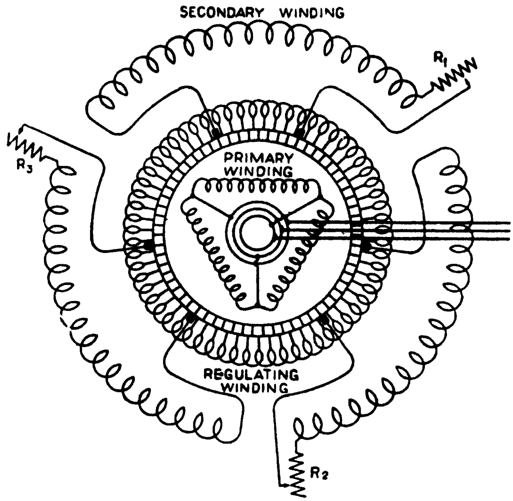



FIG. 69. DIAGRAM SHOWING ARRANGEMENT OF WINDINGS OF B.T.-H. TYPE CH A.C. COMMUTATOR MOTOR
(*B.T.-H.*)

ordinary induction motor in that the primary winding is located on the rotor and the secondary winding on the stator. In addition to the primary winding, which is connected to the supply by means of sliprings and brushes, a regulating winding is placed in the same rotor slots. This latter winding is connected to a commutator in a similar manner to the armature winding of a d.c. machine. The commutator is provided with two brush rockers which can be moved relatively to each other by means of a small pilot motor. One end of each phase of the stator winding is connected to a brush stud of one rocker and the other end of the phase to the corresponding brush stud of the opposite rocker. Hence, the greater the distance the two sets

of brushes are moved apart, the greater will be the amount of regulating winding connected in series with the secondary. The pilot motor, by moving the brushes in this manner, varies the e.m.f. injected into the secondary winding, this e.m.f. being zero when the brushes connected to the ends of the same phases of the secondary are in line, i.e. in contact with the same segments. Under these conditions the motor runs as an ordinary

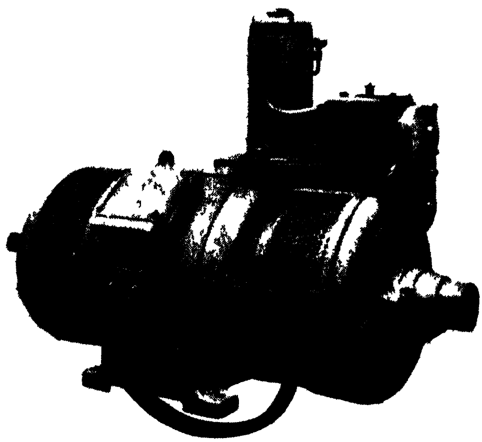


FIG. 70 A C COMMUTATOR LIFT MOTOR
*(B T -H )*

induction motor at a speed slightly less than synchronous speed. The e.m.f. which is induced by the primary in the secondary, however, depends upon the speed of rotation, being zero at synchronous speed and reaching a maximum value at standstill. The effect of the injected e.m.f. is to compel the motor to change from synchronous speed to that at which the induced secondary e.m.f. balances the injected e.m.f. By rotating the brushes in one direction or the other, the injected e.m.f. is made negative or positive, resulting in speeds below or above the synchronous speed.

Resistances *R*1, *R*2, and *R*3 may be introduced in the secondary winding to obtain creeping speeds as shown in the diagram of the motor windings in Fig. 69. The insertion of resistance,

however, adversely affects the characteristic, the speed drop from no load to full load being greater than for speed regulation by brush shifting alone.

Arrangements must be made to ensure that the pilot motor drives the brushes back to the slow speed position in the event of a stoppage from any cause. The pilot motor, which is frequently mounted on the main motor (see Fig. 70), is a small

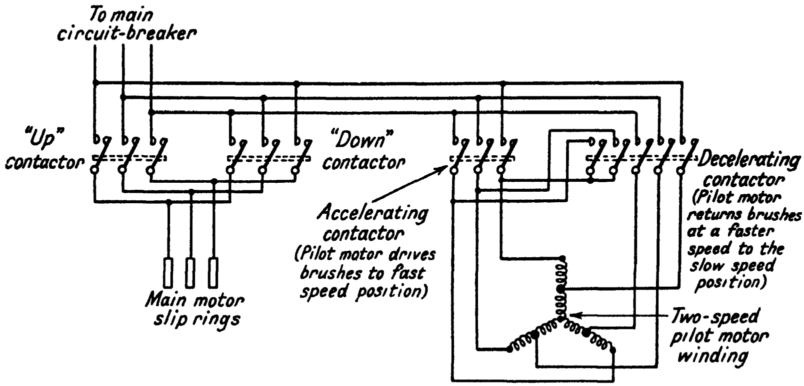



FIG. 71. THREE-PHASE A.C. COMMUTATOR MOTOR WITH TWO-SPEED PILOT BRUSH MOTOR

double-wound, two-speed, squirrel-cage motor driving a worm gear, the slow-speed and high-speed windings giving suitable brush speeds for acceleration and deceleration respectively. The motor switching connexions are shown in Fig. 71. The operating coils of the accelerating and decelerating contactors are controlled by mechanical switches operated by the pilot motor, these switches ensuring that only one contactor can operate at any one instant, and that the brushes are in their correct positions before starting.

The operating characteristics of this type of motor are very good and approach those obtained with variable voltage control; a smooth speed transition is obtained, the power factor is high over a considerable portion of the speed range, and the currents for starting and acceleration are smaller than with two-speed induction motors. Performance curves of the British Thomson-Houston Co.'s "Type C.H." lift motor are shown in Fig. 72 (*a*), (*b*), and (*c*).

In another type of a.c. commutator motor, speed regulation is obtained by a separate induction voltage regulator connected to the fixed brushes and not by moving the brushgear. This induction regulator which supplies the variable voltage to the rotor winding is of the vertical pillar type comprising a

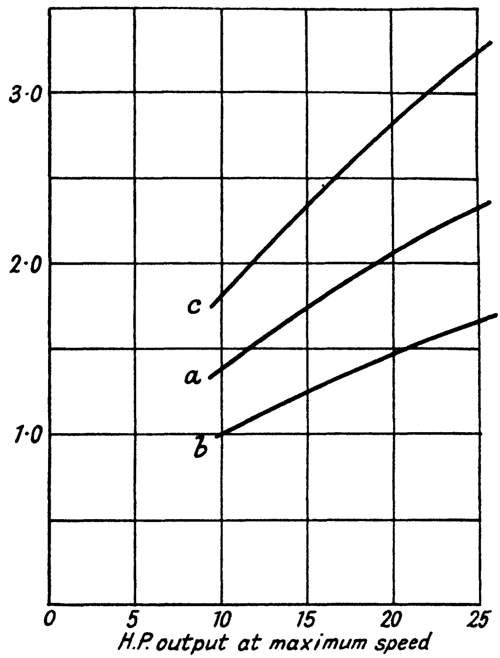



FIG. 73. CURVES SHOWING COMPARATIVE COSTS OF VARIOUS TYPES OF CHANGE SPEED A.C. MOTORS

(*a*) Change-pole slip-ring motors
(*b*) Change-pole short-circuited rotor motors
(*c*) Commutator motors

(*Metropolitan Vickers Gazette*)

stator portion and an internal rotor unit. Operation of the regulator is by a hand-wheel or pilot motor through gearing. The regulator is self-cooled by means of a motor-driven blower incorporated in the base.

The disadvantages of the commutator type motor are its high cost and the fact that it is rather noisy during operation and for these reasons it is now little used for lifts. Some idea

of the relative costs of induction and commutator motors is given in the curves in Fig. 73.

**Motors for Car Speeds of 300 ft. per min. and over.** Geared a.c. motors are in use for speeds above 300 ft. per min., but these are exceptions rather than general practice. It is not practicable to produce a gearless a.c. machine, and the gearless d.c. motor

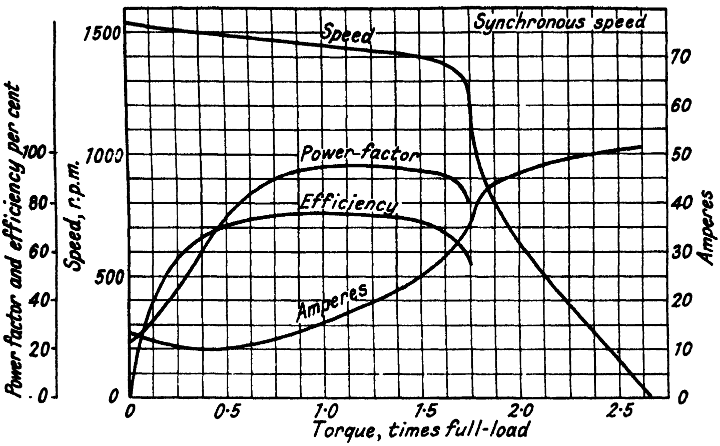



FIG. 74. TYPICAL CHARACTERISTIC CURVES OF REPULSION-INDUCTION MOTOR

Type CKS 3 816, 3 h.p., 1 450 r.p.m., 4-pole, 210-volt, 50-cycle, single-phase (*B.T.-H.*)

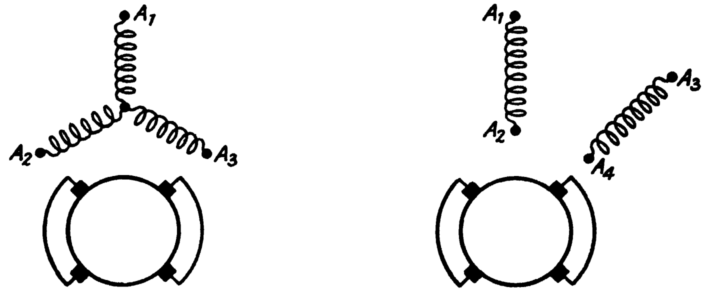
operating from a variable voltage motor generator set is the method usually employed. The mains motor is invariably of the squirrel-cage induction type

## SINGLE-PHASE SUPPLY

**Motors for Car Speeds up to about 100 ft. per min.** REPULSION-INDUCTION MOTORS. This motor starts as a repulsion motor in order to obtain the necessary high starting torque, after which, the brushes are lifted by a centrifugal governor, and the commutator short-circuited, the motor finally running as a squirrel-cage induction motor.

The "Type C.K.S." repulsion-induction motor manufactured by the British Thomson-Houston Co., however, and to which the following description refers, has no centrifugally operated

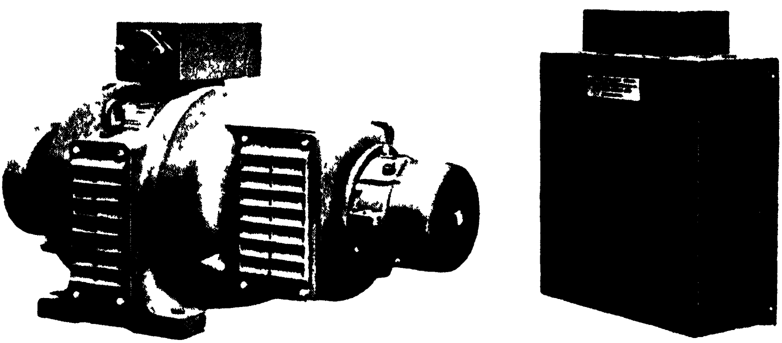
commutator short-circuiting and brush-lifting device, and the motor is, therefore, not so complicated as the usual type mentioned above. The rotor laminations have two concentric sets




(a) (b)

FIG. 75. WINDINGS OF SINGLE-PHASE REPULSION-INDUCTION MOTOR

(a) For motors up to 3 h.p.
For one rotation connect $A_1$ and $A_2$ to line
For opposite rotation connect $A_1$ and $A_3$ to line
(b) For motors above 3 h p.
For one rotation join $A_2$ to $A_3$ and connect $A_1$ and $A_4$ to line
For opposite rotation join $A_2$ to $A_4$ and join $A_1$ and $A_3$ to line
(*B.T.-H.*)



(a) (b)

FIG. 76. CAPACITOR TYPE SINGLE-PHASE LIFT MOTOR

(a) Motor (b) Condensers
(*B.T.-H.*)

of slots joined by narrow radial slits in which are placed thin metallic strips. These slots contain two distinct windings; a commutator winding (similar to a d.c. armature winding) in the outer slots and a cast aluminium squirrel-cage winding in

the inner slots. The stator is wound with a simple single-phase winding.

During the starting and accelerating periods, the flux produced by the stator winding links with the outer winding only, due to the high reactance of the squirrel-cage, and the motor acts as a repulsion motor giving a high starting torque. As the motor accelerates, the reactance of the squirrel-cage decreases, so that more and more of the flux links with this

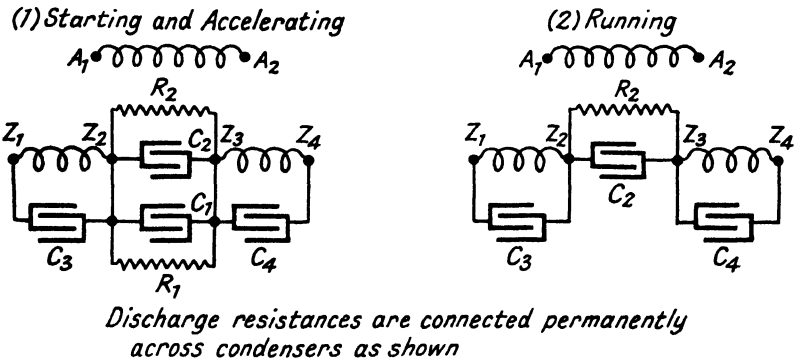



FIG. 77. CONNEXIONS OF SINGLE-SPEED SQUIRREL-CAGE CAPACITOR LIFT MOTOR

| | | | |
|---|---|---|---|
| $A_1, A_2$ | Main winding | $C_1$ | Starting condenser |
| $Z_1, Z_2$ / $Z_3, Z_4$ | Auxiliary winding | $C_2, C_3, C_4$ | Running condensers |
| | | $R_1, R_2$ | Discharge resistances |

For one rotation connect $Z_1$ to $A_1$, and $Z_4$ to $A_2$; and for other rotation connect $Z_4$ to $A_1$, and $Z_1$ to $A_2$ and connect $A_1$ to line 1 and $A_2$ to line 2.

(*B.T.-H.*)

winding and both windings now assist in the acceleration, thereby producing a large torque. On light loads, i.e. at speeds above the synchronous speed, the squirrel-cage exerts a braking torque and prevents the speed from increasing to more than 2 per cent or 3 per cent above the synchronous speed.

The motor is started by switching direct on the lines, the starting current being approximately 3½ times the full load current, whilst twice the full load torque is developed. The starting current may, if required, be reduced by inserting an external resistance in the line circuit, when the torque developed will be reduced as the square of the starting current. Typical characteristic curves of this motor are shown in Fig. 74, and the arrangements of the motor windings in Fig. 75.

With high efficiency gearing and an overhauling load, it is possible for the torque developed to be insufficient to effect reversal of rotation of the motor in the event of the car switch

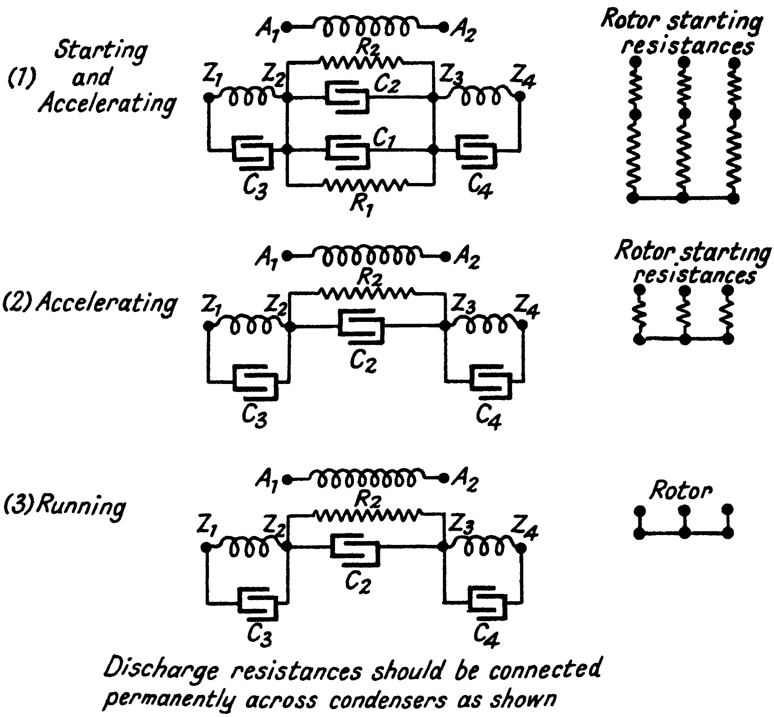



FIG. 78. CONNEXIONS OF SINGLE-SPEED SLIP-RING CAPACITOR LIFT MOTOR

| | | | |
|---|---|---|---|
| $A_1$, $A_2$ | Main winding | $C_1$ | Starting condenser |
| $Z_1$, $Z_2$ / $Z_3$, $Z_4$ | Auxiliary winding | $C_2$, $C_3$, $C_4$ | Running condensers |
| | | $R_1$, $R_2$ | Discharge resistances |

For one rotation connect $Z_1$ to $A_1$ and $Z_4$ to $A_2$; and for other rotation connect $Z_4$ to $A_1$ and $Z_1$ to $A_2$ and connect $A_1$ to line 1 and $A_2$ to line 2

(*B.T.-H.*)

being instantly reversed. A time delay is therefore provided in conjunction with the main reversing contactor in order to delay the reversal by approximately 0·5 sec., to enable the brake to operate and reduce the motor speed. The motor will then develop the necessary reverse torque.

Capacitor Motors. During recent years the cost of condensers has been reduced and their reliability increased, and this has made practicable the use of capacitor motors for single-phase lifts. This motor is quieter than the repulsion-induction motor and may be of either the squirrel-cage or slip-ring type, the latter being employed for the larger sizes.

Electrically, these motors are, in effect, of the two-phase induction type, but operate on a single-phase supply, this being accomplished by the use of condensers which are housed in a separate metal capacitor unit as shown in Fig. 76. The stator has two windings; a main and an auxiliary winding displaced electrically by 90°, the condensers being connected to the latter winding. To obtain the high starting torque required for lift service and to ensure quiet running, the value of the capacitance at starting must considerably exceed that at full speed, and the effective capacitance must therefore be reduced as the motor speed increases. This is accomplished automatically by a centrifugal switch which operates at a predetermined speed, and as the motor slows down the switch resets ready for the next start.

The starting current of the squirrel-cage type is $3\frac{1}{2}$ times full load current. The connexions for starting, acceleration, and running are shown in Fig. 77.

The slip-ring type has a lower starting current ($2\frac{1}{4}$ times full load current) for an equivalent torque than the squirrel-cage type, and is used when the supply authority imposes starting current limitations. The condenser and winding connexions are shown in Fig. 78.

Another method of obtaining a lift drive from a single-phase supply is to employ a rectifier and use a d.c. motor. Except when grid-controlled rectifiers are used, however, this method has the disadvantage that dynamic braking is not possible unless some other form of rotating machinery is also being supplied by the rectifier, and will thus allow the lift motor to function as a generator.

**Motors for Car Speeds between 100 ft. per min. and 250 ft. per min.** A rectifier and a d.c. motor may be used or a motor generator set and variable voltage control.

**Motors for Car Speeds of 300 ft. per min. and over.** The gearless d.c. machine with a motor generator set, the motor being wound for single-phase working, is the best practice.

## CHAPTER VI

### VARIABLE VOLTAGE EQUIPMENT

THE variable voltage or Ward-Leonard method is the best for varying the speed of gearless motors, but it is also successfully employed with high grade geared d.c. machines. The results obtained are far better than those given by rheostatic methods, in which series and diverting resistances are used.

A motor generator set is employed, the generator of which supplies voltage to the lift d.c. motor; the motor of the set receiving its supply from the mains. The set motor is a standard, constant speed machine, the type used depending upon the characteristics of the power supply available, whilst the generator is usually a shunt-wound d.c. machine, having its armature permanently connected (electrically) to the armature of the lift motor. When the mains supply is a.c., a small exciter is installed in addition to the motor generator set to provide the direct current for the lift motor and generator fields and magnets of the brake and control gear. In recent years it has been the practice to dispense with an exciter and obtain the necessary d.c. supply from a static rectifier. Automatic levelling may be performed without the use of an auxiliary machine, and in these cases the generator is provided with an additional shunt field which supplies the low voltage necessary to drive the lift motor at the slow levelling speed.

Since the lift motor receives its supply from the generator it is seen that the speed and direction of the car travel vary with the magnitude and polarity of the generator voltage, these in turn depending upon the strength and direction of the generator field. Acceleration of the car is obtained by strengthening the generator field, the lift being brought up to its final full speed by weakening the lift motor field. Retardation is effected by reversing these operations.

The advantages of this type of control are—

(i) The acceleration and retardation are smoother than that which is obtainable with any other form of control, as the generator voltage is free from any sudden changes.

(ii) It may be used on any supply by employing a suitable driving motor.

(iii) The controller is comparatively simple and its contactors need only be constructed to handle small currents of the order of a few amperes, as opposed to the large contactors handling the full power as in the case of rheostatic control.

(iv) The maintenance and running costs are relatively low since the controller, usually the chief source of trouble, is simple, and there are no rheostatic losses when accelerating, retarding, or running at reduced speeds.

(v) Its ability to re-generate to the supply mains.

When car switch control is employed the motor generator set is started by pressing a button fitted in the car, and the attendant can therefore shut down the set during slack periods. With automatic control, however, an automatic shut-down device is often incorporated, and is adjusted so that if no calls are received for, say, ten minutes, the motor generator set is automatically stopped, and motor generator stand-by losses are therefore eliminated. When a call is received the set is automatically started, but the car will not start until the motor generator full speed has been attained.

**Speed Regulation.** The speed/load characteristic of the set as a whole is a falling one and some method is invariably adopted to raise the characteristic, i.e. to make the speed independent of car load variations. To provide accurate floor levelling, however, it is desirable in practice to arrange that the motor speed when lifting full load is slightly higher than the no-load speed, and this involves a rising characteristic. This artificial variation is introduced so that the amount of brake slip when lifting full load is practically the same as when lowering full load (see Chapter XIII).

Several methods have been used for improving the regulation, one of which is the over-compounding of the generator field to give an increase in generator voltage when operating against full load. When the load is overhauling, however, and the lift motor functions as a generator, the current in the series winding is reversed and opposes the current in the shunt field. The series winding, being designed primarily for use when the generator is supplying current to the winding motor under full load conditions, is therefore generally of such a strength that

it is possible for the series winding to overpower the shunt field. This is guarded against by incorporating some device which, when the lift motor operates as a generator, automatically and gradually shunts the current flowing through the series winding and thus prevents overpowering of the shunt field.

Another method, and one which has proved satisfactory, makes use of a separate small booster, whose armature is connected in series with the generator shunt field, and its field in series with the generator armature, as in the diagram in

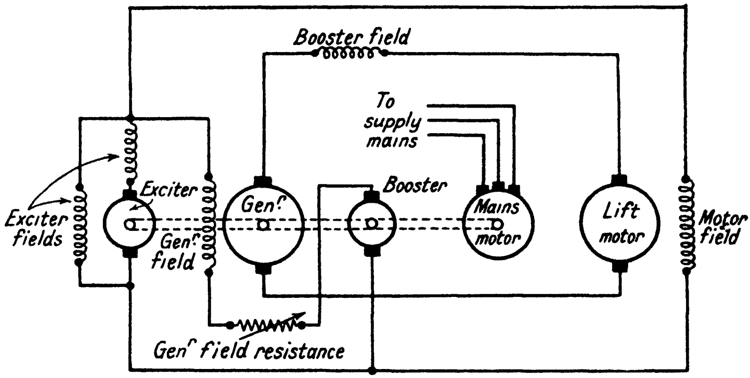



FIG. 79. VARIABLE VOLTAGE SET WITH BOOSTER AND EXCITER

Fig. 79. Hence, as the generator load increases, the speed of the lift motor tends to decrease, but the booster generates a correspondingly increased e.m.f., thus boosting the generator shunt field and holding up the lift motor speed. With an overhauling load, the generator armature current and booster field current are reversed, and thus the voltage generated by the booster is also reversed. The resultant generator field and output voltage are therefore reduced in values, and this counteracts the tendency of the overhauling load to produce an increase of speed.

A modification of the above method consists of a motor generator set, the generator of which has a common armature winding specially elongated to embrace the two separate (generator and booster) field systems, and one commutator together with its brush gear is therefore eliminated. The principle of this arrangement is shown in Fig. 80. The generator

field system has shunt and interpole windings but no series windings. Demagnetizing windings are superimposed on the shunt field poles, the former being in use only during stopping and whilst the lift is stationary. The booster field system has three sets of series windings and by this means four combinations of windings can be obtained to give various values of boost. The booster field system also has a demagnetizing winding in series with that on the generator field, so that the two always

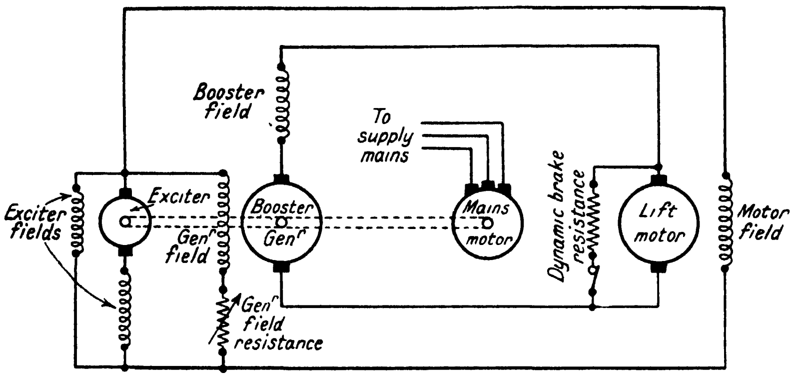



Fig. 80. Variable Voltage Set with Generator and Self-contained Booster

function simultaneously when brought into action. A controller diagram which incorporates this set is shown in Chapter XV. During operation the current generated in the armature passes through the booster field on its way to the lift motor winding. If the lift machine is "motoring," then the loop current passing through the booster field winding generates a voltage in the armature which is added to the generator voltage. This ensures a rising voltage on the loop circuit with increase in "motoring" load and is so arranged to give a flat or slightly rising speed characteristic. If the lifting machine is "generating," then the generated current passing through the booster field winding generates a voltage opposed to the generator voltage already present. This ensures a decreasing voltage on the loop circuit with increase in generating load. It will be noted that there is no interaction between the two field systems but simply an arithmetical addition or subtraction of volts to or from the

generator volts as the load changes in magnitude and characteristic.

A four-unit variable voltage set manufactured by the British Thomson-Houston Company is shown in Fig. 81, and a sectional arrangement showing the constructional details in Fig. 82. This set comprises a d.c. variable voltage generator flexibly coupled to a skirt-mounted a.c. induction motor and separately

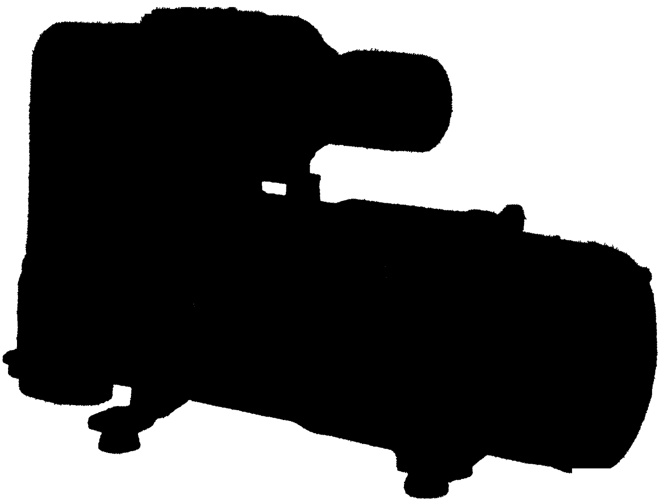


Fig 81 Variable Voltage Motor generator Set with Exciter (*B T-H*)

excited from a Vee-belt driven exciter mounted on top of the generator. A small series booster or control exciter is mounted on top of the set and direct-coupled to the main exciter. For variable voltage geared drives this small series exciter is not provided. The set is arranged for three-point support (without a base plate) on pads of resilient material which also help to prevent any noise or vibration being transmitted to the building. The generator frame, commutator endshield and skirt are of welded steel, and each machine has spring-loaded ball-bearings. One advantage of the belt-driven exciter is that the same set can be used on a 50- or 60-cycle supply merely by changing one pulley. On the smaller powered units requiring

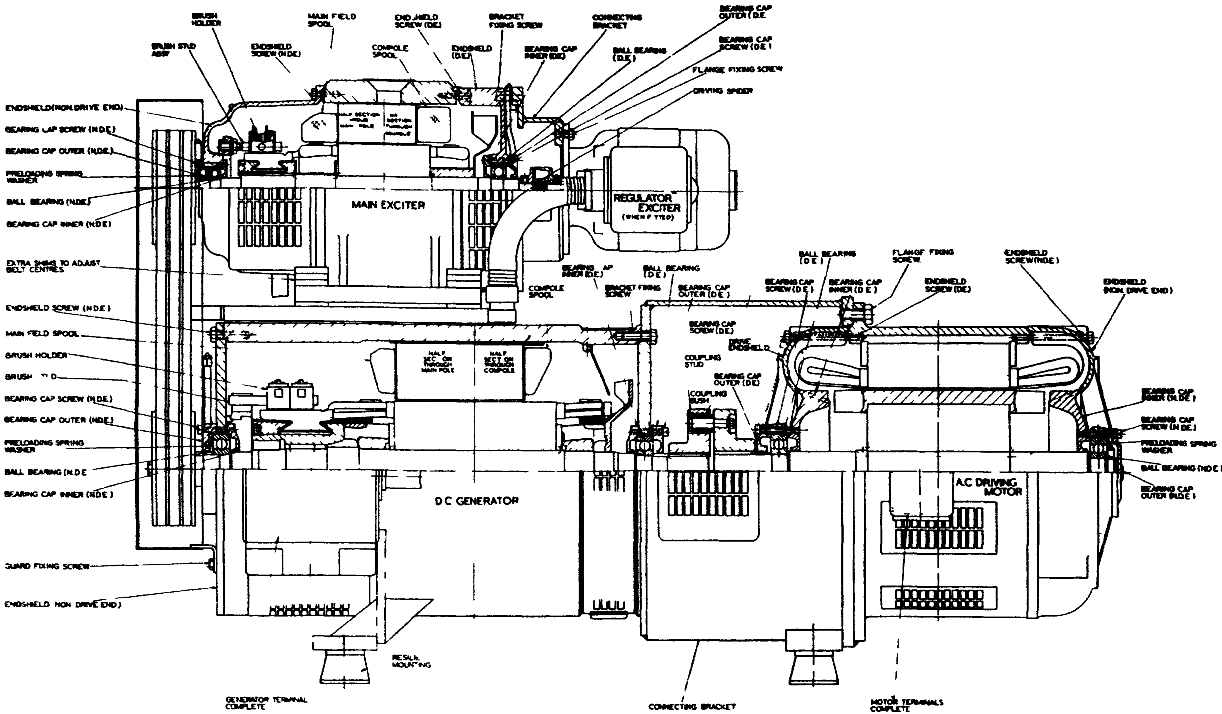



**Fig. 82. Sectional Arrangement of Variable Voltage Motor-generator Set (B T-H)**

less power for excitation it is sometimes more economical to use a rectifier instead of an exciter, and the variable voltage set in these cases is a simplified two-unit arrangement.

The circuits for the speed control of this set are shown in Fig. 83, which includes in addition to the series exciter a small

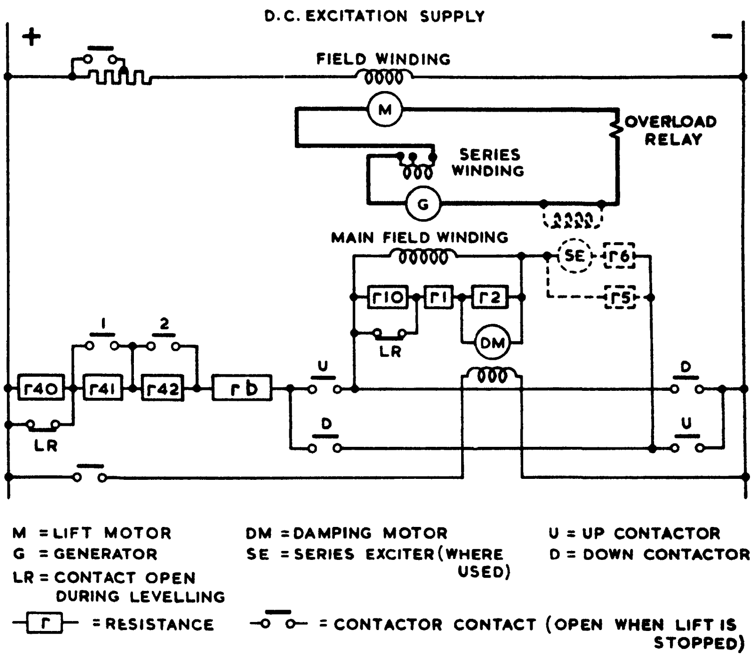



FIG. 83. CIRCUITS OF VARIABLE VOLTAGE MOTOR-GENERATOR SET (*B.T.-H.*)

damping motor for speed control, connected across the generator main field winding. The levelling speed is adjusted to approximately 20–25 ft. per minute by means of the resistances *r*1, *r*2, and *r*40. Resistance *r*1 is adjusted to its minimum value and *r*2 to about three-quarters of the resistance of the generator field. This levelling speed may be raised by decreasing *r*40, and vice versa. The intermediate speeds are raised by decreasing *r*41 or *r*42, and vice versa, whilst the full speed is raised by decreasing *rb*, and vice versa. Adjustment of the "compounding" (the relation between lift speeds, particularly levelling

speeds, during hauling or overhauling conditions) is made by altering the series field strength of the main generator, this being done by adjustment of the tappings of the field coils. Alternatively this may be effected by providing an adjustable

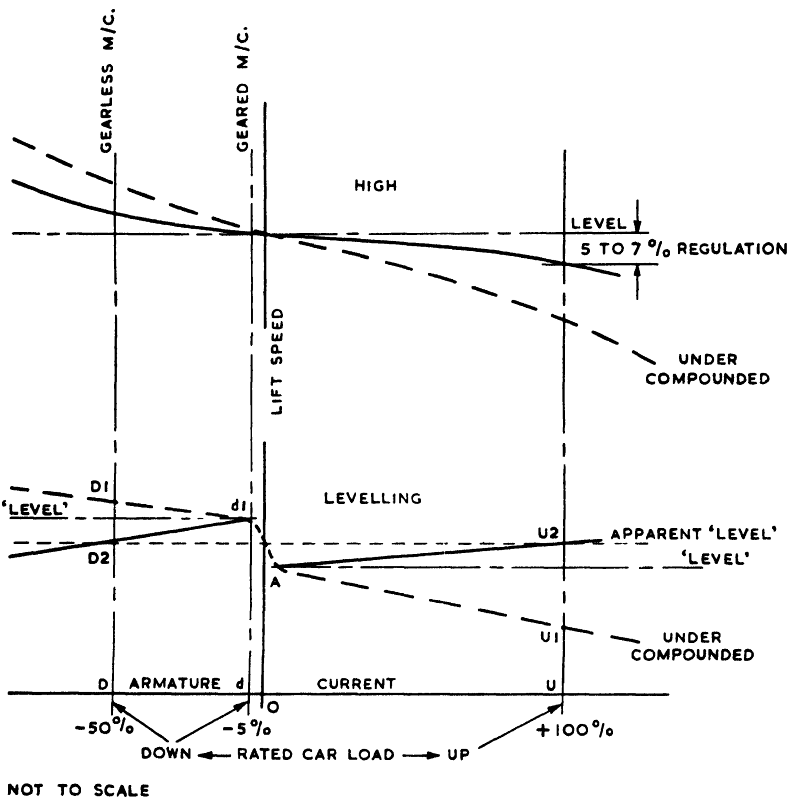



FIG. 84. SPEED CURVES FOR VARIABLE VOLTAGE SETS (*B.T.-H.*)

diverter resistance across the field coils. Increasing the number of series field turns in circuit or increasing the diverter resistance will increase the "compounding," i.e. with an empty car the lift speed DOWN will exceed the corresponding speed UP. A further adjustment of "compounding" at a full speed is provided by the series exciter whose effect is adjusted by

resistances $r5$ and $r6$. These should be adjusted so that the speed DOWN is about 5 per cent less than the UP speed. Increasing $r5$ will increase the "compounding," and vice versa. The first step of speed regulating resistance to be cut, $r41$ determines the value of the first peak current. Decreasing $r41$ reduces this peak current. Decreasing $r2$ also gives a finer adjustment in reducing the starting peak current and so softens the acceleration and makes the starting "surge" less noticeable. To increase the quickness of response when starting, $r1$ is increased in small steps. The quickness of response when levelling is increased by increasing $r10$. Decreasing $r2$, $r1$, or $r10$ also has the effect of reducing the steady speeds.

The adjustment of the "compounding" and levelling speeds may be clearer from a consideration of Fig. 84, which shows typical speed curves at low and high speeds for geared and gearless machines. The speeds (ordinates) are plotted against armature current expressed as a percentage reading of a moving-coil ammeter. There are four ordinates drawn, viz.—

At $D$, $-$ 50 per cent F.L. current, or Empty Car UP, also contract load DOWN; Gearless machine. (The actual figure may vary from 50 per cent.)

At $d$, $-$ 5 per cent F.L. current, or Empty Car UP, also contract load DOWN; Geared machine. (The actual figure may differ, or sign may be $+$.)

At $O$, Zero current in the lift motor.

At $U$, $+$ 100 per cent F.L. current, or contract load UP, also Empty Car DOWN, for both types.

Curve $D_2d_1AU_2$ represents speed curve for Gearless machine, apparently level-compounded.

Curve $d_1AU_2$ represents speed curve for Geared machine, apparently under-compounded.

Curve $D_1d_1AU_1$ represents speed curve for Gearless machine under-compounded.

Curve $d_1AU_1$ represents speed curve for Geared machine under-compounded.

NOTE. Level-compounding is obtained when lines $D_1d_1$, and $AU_1$ are parallel to the $X$ axis. $U_1$ will then be slightly less than $D_1$ or $d_1$. It will be seen that curve $D_2d_1AU_2$ shows actual over-compounding. Curve $d_1AU_2$ also shows actual

over-compounding. The cranked curve prevents these facts from being appreciated when only two readings, UP and DOWN, are taken.

It will be noted that, with the geared machine, point $d_1$ will not change appreciably as the compounding is changed, because the current at this point is so small.

At high speed, the compounding is set so that the speed drop between no-load and rated load UP is from 5 to 7 per cent. As will be seen from the curves, this is more important for the

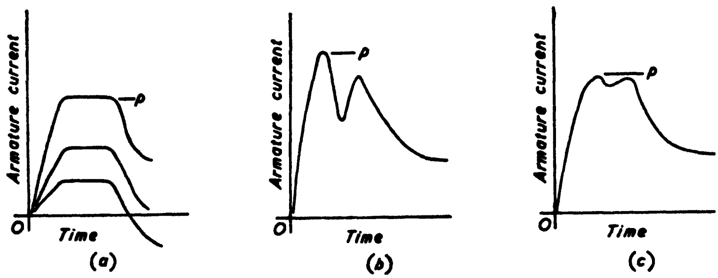



FIG. 85. ACCELERATION CURVES FOR VARIABLE VOLTAGE SETS (*B.T.-H.*)

gearless machine, as serious under-compounding may cause the overspeed device to trip.

Fig. 85 shows the results of adjustments of acceleration and "peak current" limitation, the maximum peak current being measured by an ammeter in the armature loop circuit when accelerating the car UP with contract load. At steady speed the current will fall to a value representing the out-of-balance load plus friction.

Curves (*a*), (*b*), and (*c*) show typical armature current curves, during acceleration plotted against time. The time taken to accelerate will be from 1·5 to 3 seconds according to the particular lift being considered. These three curves assist in recognition of the type of accelerating curve by observation of the ammeter. Curves (*a*) are three curves for contract load UP (biggest current), balanced load, and contract load DOWN. The flat top shown in practice by the ammeter pointer remaining fairly steady during acceleration period, then falling off, shows that the best possible use of the machines is being made and is ideal. Curve (*b*) shows contract load UP only. The

ammeter pointer flicks quickly up and down. This type of curve is associated with serious sparking and a surge sensation at starting. It feels like quick acceleration, but the equipment is badly adjusted and the best use is not being made of the machines. Curve (*c*) shows a well-adjusted compromise. The ammeter pointer moves more slowly and is steadier. The

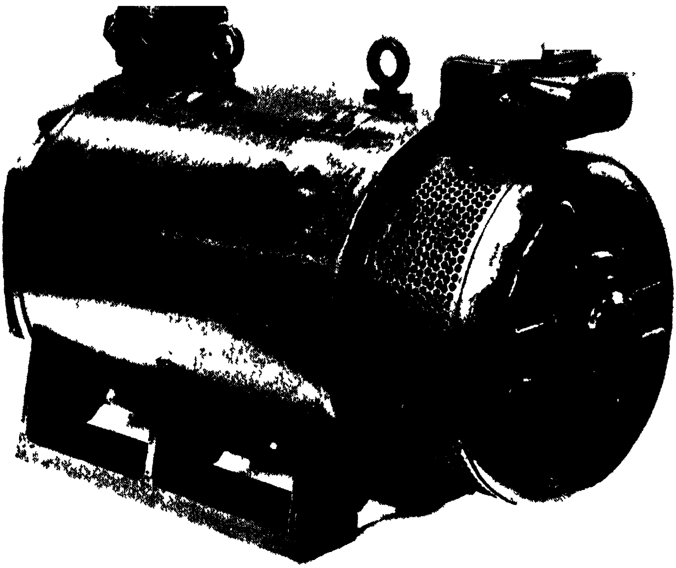


FIG. 86. VARIABLE VOLTAGE MOTOR-GENERATOR SET
(*Bull Motors*)

second peak is nearly equal to the first, and the "dip" between them is small. The machines are being used quite effectively, and the accelerating distance will be little different from (*b*). The sensation when riding in the car is of smooth acceleration. Curve (*c*) shows the kind of curve that is to be desired. The improvement shown by (*c*) over (*b*) is, generally, due to lower values of resistances *r*1 and *r*2. In each case the maximum peak current is indicated by *p*. *p* should not be allowed to exceed the maximum current permitted for the machines in question.

In order to make use of the damping motor, the resistances $r41$, $r42$, etc., must not be cut out all at once; at least two steps, separated by a time interval, are essential. Acceleration in one step renders the damping motor practically useless, and results in a single very large peak of current with corresponding severe effects.

A single unit variable voltage motor-generator set, manufactured by Bull Motors, is shown in Fig. 86, viewed from the generator end. The generator embodies a tapped series winding and a differential shunt field winding. Control of the generator output is by a rheostat or a damper motor, the armature of which is connected across the generator main field.

**Electronic Variable Voltage Control.** This system provides a variable voltage supply to a d.c. motor by means of a grid controlled rectifier instead of a Ward-Leonard motor-generator set. A mercury-arc rectifier is used, the phase relationship of the grids to the anodes and hence the rectifier output voltage being controlled by a rotary phase-shifting regulator which is driven directly from the lift. The regulator is driven from a camshaft which can be coupled by magnetic clutches, "Accel," or "Decel," to a chain drive from the lift gear either to run forward to accelerate or backwards to decelerate. Thus the movement of the regulator and so the rate of acceleration or deceleration are controlled directly and automatically by the speed and position of the car in the well.

The rectifier equipment consists of a main oil-immersed transformer feeding either a single bulb rectifier for the small equipments or two bulbs for large sizes of over 40 h.p. The controlling grids are inserted between the cathode and the anode and a potential is applied to these grids through the phase-shifting regulator and the transformer so that the phase relationship between the control grids and the anodes can be varied through 120 electrical degrees. When a negative potential is applied to the grid, the anode, which the grid controls, cannot fire. As soon as the grid potential becomes positive to the cathode, electron flow takes place from cathode to grid and from cathode to anode, which is a positive flow to current from anode to cathode. Thus, by adjusting the moment at which the grid becomes positive to the cathode, it is possible to control the firing of any anode throughout its normal firing

period, and this leads to complete control of the output d.c. voltage. A rotary inductor type regulator may be used or a static type electro-magnetic phase shifter. The circuit of a 23·5-kW rectifier with control gear and rotary induction type phase-shifter is shown in Fig. 87, whilst Fig. 88 is a typical gear of this type under test, showing the chain drive to the controller camshaft and the rectifier cubicle which contains the

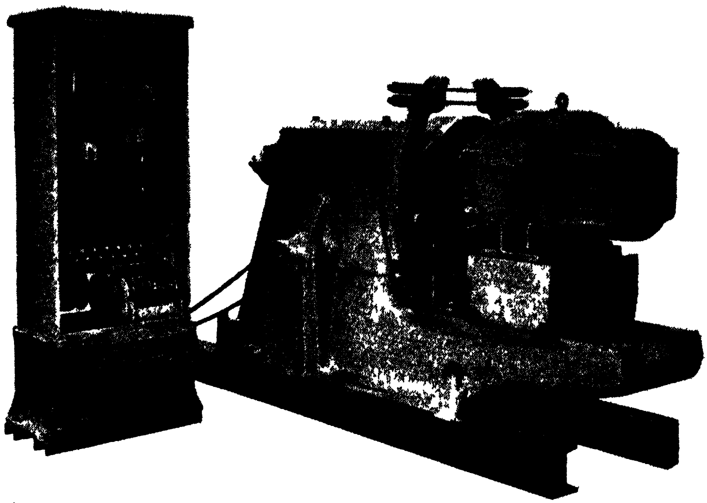


FIG. 88. ELECTRONIC CONTROL VARIABLE VOLTAGE LIFT
(*Wm. Wadsworth & Sons*)

transformer at the rear. A controller of this type is described in Chapter XV.

**Electronic Control of Ward-Leonard Motor-generator Set.** In a similar manner the variable voltage output of the grid-controlled mercury-arc rectifier can be employed for energizing the shunt field of the generator of a normal Ward-Leonard set. The control of the grid, and hence the rectifier output voltage, is by a tachometer generator driven directly by the lift gear. Fig. 89 shows the circuits required for this form of control.

A rheostat is connected across a suitable constant voltage source and has contacts connected to as many tapping points as may be required to give smooth control, the contacts being

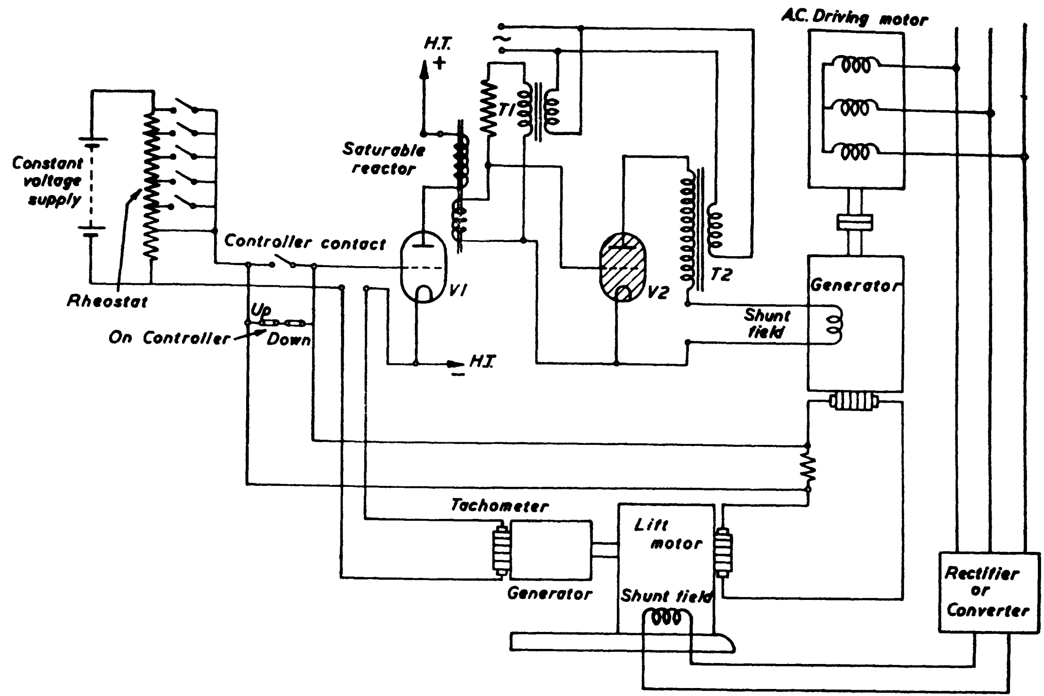



FIG. 89. ELECTRONIC CONTROL OF WARD-LEONARD SET
(*Wm. Wadsworth & Sons*)

actuated by a camshaft positively driven in unison with the lift car. The voltage developed across the rheostat, which depends on the speed and/or position of the lift car in the well, is applied, when a controller contact is closed, directly to the control grid of a thermionic valve $V1$. Other contacts UP DN are connected across this contact, as also is a variable resistance connected in one of the supply lines to the armature of the lift motor. The output of a tachometer generator driven by the lift motor is fed into a conductor from the rheostat to the cathode of $V1$. The anode of $V1$ is supplied with high-tension voltage from a convenient source, and the anode circuit includes a winding of a saturable reactor, the other winding of which is connected to the grid and cathode of a gas-filled rectifier $V2$. A transformer $T1$, the primary of which is supplied with alternating current, has a resistor and the reactor winding connected in series across its secondary. A further transformer $T2$, connected to the same a.c. source, supplies the anode of $V2$, the rectified anode current passing also through the field winding of a generator supplying the lift motor, and driven by a three-phase a.c. motor. The three-phase supply is connected also to a rectifier or rotary converter supplying the lift motor field.

When the lift car is at rest, the rheostat contacts and controller contact are open, and contacts UP DN are closed. When the UP contactor is energized, contact UP opens, and the lift starts to move, closing the controller contact and the rheostat contacts in succession by means of a camshaft. A voltage equal to the difference between the voltage across the rheostat and that of the tachometer generator is then applied to the grid of $V1$, the rheostat voltage increasing gradually as the contacts are closed. The anode current of $V1$, flowing through the reactor winding, controls the permeability of the core of the reactor, and hence the inductance of the second reactor winding. This winding and resistor form a circuit in which, by variations in the inductance of this winding, the phase of the alternating voltage (derived from transformer $T1$) applied to the grid of $V2$ is varied in relation to the a.c. input and hence in relation to the voltage at the anode of $V2$. In this way the portion of the a.c. cycle over which $V2$ is conducting is varied in accordance with the grid voltage of $V1$, and consequently

the mean excitation of the field of the generator, and hence the lift motor input depends on this grid voltage.

As the grid voltage is the difference between the rheostat voltage and the tachometer voltage, any depression of the motor speed due to a load thrown on to the motor, results in an increase of the grid voltage and a corresponding increase in the motor input. On light load, an increase of the motor speed results in a decrease in the motor input. There is thus a stabilizing action, the motor tending to maintain a speed which makes the tachometer voltage nearly equal to the rheostat voltage. As the successive rheostat contacts are closed, the voltage increases and the motor speed also increases, until all the contacts are closed, when the speed is kept constant at its maximum value.

When the lift car approaches a floor, a switch in the shaft, or other equivalent means, causes the camshaft to open the rheostat contacts successively, thereby slowing down the lift, and finally to open the controller contact. The voltage developed across the resistor, depending on the lift motor torque, is then added to the rheostat voltage, so that the speed of the motor depends partly on the torque. The speed now reached depends on the load in the lift car in such a manner as to counteract the effect of the load on the slide of the lift when the brake is applied and the motor de-energized, and consequently to reduce the variation in levelling caused by varying loads in the car.

When the UP contactor is de-energized, the contact UP closes, and when the down contactor is energized the contact DN opens. The contacts UP and DN could be replaced by a single contact, opened whenever the lift moves, or further contacts may be added across or in series with the controller contact as required.

With this arrangement the speed of the lift motor is closely proportioned to the voltage developed across the camshaft-operated rheostat, and the input to the motor at starting and stopping is related to the motor torque.

# CHAPTER VII

## BRAKES

It is important that a lift brake shall be of good design and that the number of wearing parts shall be kept to a minimum in order that it may maintain its adjustment for long periods without attention. Accurate and reasonably constant brake adjustments are essential, as a badly adjusted brake can be responsible for inaccurate floor levelling and consequent "inching," accompanied by greater wear on the controller contacts and an increase in the energy consumption.

**Braking Torque.*** A lift brake must be sufficiently powerful to stop the fully loaded car when travelling at levelling speed, within the distance between the stopping switch and the landing and therefore must be capable of absorbing the kinetic energy of the lift moving parts. In an accurately designed installation, this indicates that the braking torque should be approximately equal to the motor torque at levelling speed.

$$\text{Motor h.p.} = \frac{\text{torque} \times 2\pi N}{33\,000}$$

$$\therefore \text{torque} = \frac{5\,250 \times \text{h.p.}}{N} \text{ lb. ft.}$$

where $N$ is the revs. per minute of the brake drum when the motor is rotating at levelling speed.

In practice, however, the above braking torque is larger than is necessary, because part of the lift kinetic energy is absorbed by friction in the gear box, bearings and guide shoes, and as the motor is usually the nearest commercial size, its h.p. is more than adequate for the purpose. Further, when the brake operates, it converts the kinetic energy of the lift into heat which is dissipated in the brake and drum. It is therefore necessary to consider also the frequency of operation of the brake, i.e. the number of stops per hour of the lift, to ensure that the brake drum can dissipate the heat without causing the brake lining to be heated beyond its working temperature.

* "The Choice of Magnetic Brakes," by C. F. R. Fielden—*Metro-Vickers Gazette, Nov.*, 1947.

It is thus advisable to ascertain the braking conditions in more detail than is given by the above formula and this may be done as follows—

If $d$ ft. is the distance of the car from the landing when the power is cut off, then the time $t$ for the car to reach the landing is $d\Big/\dfrac{v}{2 \times 60} = \dfrac{120d}{v}$ sec. (which is also the time during which the brake is in operation), where $v$ is the levelling speed in ft. per minute. This is not strictly correct because some small part of $t$ is expended in contactor operation and in applying the brake shoes to the drum.

The brake retarding torque $T = I\alpha$, where $I$ is the moment of inertia of all moving parts referred to the brake drum and $\alpha$ the angular retardation of the drum.

But $I = \dfrac{Wk^2}{g}$ and $\alpha = \dfrac{\omega}{t} = \dfrac{2\pi N}{60t}$ radians per sec. per sec.

where $W$ is the weight of all moving parts treated as if they were all at a distance $k$ (the radius of gyration) from the drum shaft, and $\omega$ is the drum angular velocity in radians per second.

Hence $T = \dfrac{Wk^2}{g} \times \dfrac{2\pi N}{60t} = \dfrac{0{\cdot}00325\ Wk^2N}{t}$ lb. ft.

The moment of inertia of the equipment referred to the brake drum is calculated as follows—

Let $I_1$ = the moment of inertia of the motor rotor, brake drum and worm in lb. ft.$^2$

$I_2$ = the moment of inertia of the worm wheel and sheave in lb. ft.,$^2$ and this will be small compared with $I_1$.

$N_1$ = the revs. per minute of the worm wheel and sheave.

$L$ = the contract load in lb., and assume that the counterweight is balanced for half load.

$r$ = the radius of the sheave in ft.

The moment of inertia of the motor, brake drum and worm $= I_1$ lb. ft.$^2$

The moment of inertia of the worm wheel and sheave

$$= I_2 \left(\frac{N_1}{N}\right)^2 \text{ lb. ft.}^2$$

The moment of inertia of the car and load

$$= \frac{L}{2} r^2 \left(\frac{v}{2\pi r N}\right)^2 = \frac{Lv^2}{8\pi^2 N^2} \text{ lb. ft.}^2$$

The sum of these three is the total moment of inertia at the brake drum ($I$). The values of $I_1$ and $I_2$ can be calculated from the dimensions and weights of the parts.

If the lift makes $S$ journeys per hour and $t_1$ seconds is the average time of each trip, then $\frac{S(t_1 - t)}{360}$ is the fraction of each hour that the brake coil is in circuit. For such duties as lift service the brakes usually have intermittent ratings of 33 per cent or 50 per cent which indicate that the coils should be in circuit for not more than 5 minutes in 15 minutes, or 5 minutes in 10 minutes respectively.

The energy which has to be dissipated by the brake drum depends largely on the lift duty, the amount dissipated per hour being $S \times$ the total energy of the moving parts at levelling speed.

As the speed of a lift brake drum does not usually exceed 1 000 r.p.m. the maximum safe speed of the drum will not be exceeded even on the larger size brakes.

After calculating the various factors governing the brake size as outlined above, a suitable brake can be selected from a manufacturer's catalogue which usually specifies such particulars for the different sizes of brakes listed.

**Types of Brake.** The most common form of lift brake is constructed on the electromagnetic principle, and in the majority of cases is situated between the motor and the gearbox, i.e. on the high speed side, where it has the greatest mechanical advantage. In a gearless lift the brake is fitted between the motor and the driving sheave. So that the brake may be capable of sustaining the car when the motor armature is withdrawn for repairs, the brake drum is fitted on the worm shaft side of the coupling. The shoes, usually in two parts, are lined with Ferodo or similar material and sometimes function as independent units in order that, in the event of a failure of one half, the other will be available for braking. Operation of the shoes is effected by spiral springs, and release by means of an electromagnet, the solenoid of which acts upon the brake shoes

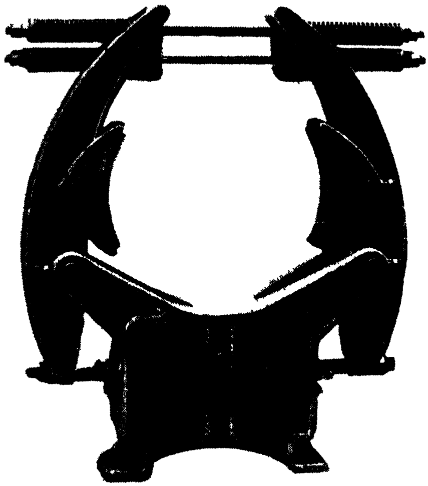


FIG. 90. ELECTROMAGNETIC BRAKE
(Electromagnet below and springs above)
(*Wm Wadsworth & Sons*)

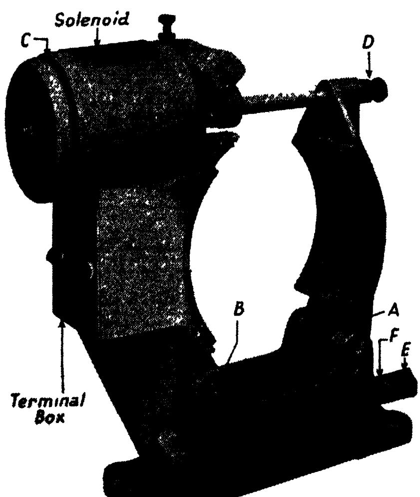



FIG. 91. DIRECT CURRENT ELECTROMAGNETIC BRAKE
(*Dewhurst & Partner, Ltd*)

either directly or through a system of links. The disadvantage of links and pins is that small wear on the pins may result in a comparatively large amount of lost brake motion. In some forms, the electromagnet is placed below the shoes and the springs above, as in Fig. 90, whilst in others this arrangement is reversed, an example of which is seen in Fig. 91. In yet another type both solenoid and springs are placed above the shoes, as in the brake shown in Fig. 92. A brief description of the brake seen in Fig. 91 will serve to illustrate the principle of operation and the method of adjustment of a well-designed brake. In the type shown, wear is possible only at the brake linings and the pins *A* and *B*, and as the radial movement of the pins is less than 1° and the bearing surface $5\frac{1}{2}$ times the pin diameter, the wear on these pins is very small. Wear on the linings results in an increase of the air gap at *C* which is corrected by withdrawing the set screw *D* as required. The shoes are applied by a compression spring situated in the brake base-block and released by a solenoid acting directly upon the shoes. The strength of the spring and hence the force exerted by the shoes may be adjusted by the screw *E*. The adjustment for maximum torque is made at the works, after which a steel collar *F* is fitted to prevent further compression. If the maximum torque is not required, the adjusting stud can be screwed back. In the 12 in. size, which develops a torque of 300 lb. ft., the spring is 9 in. long, $1\frac{1}{2}$ in. diameter and the spring movement during operation is only $\frac{1}{64}$ in. The solenoid windings are totally enclosed and protected from dirt, damp, and mechanical damage.

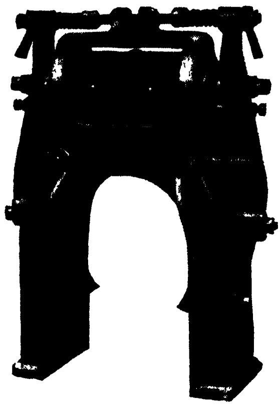


FIG. 92
ELECTROMAGNETIC BRAKE
(Electromagnet and springs above)
(*J. & E. Hall, Ltd.*)

The method of adjusting the brake shown in Fig. 91 is typical of the adjustment of any solenoid-operated lift brake. The brake is first set to the "Off" position by unscrewing the adjusting screw *E* after making sure that the electricity supply is cut off. Adjust the gap between the lining of each brake shoe and the drum to a minimum by means of the heel screw and

its lock nut at the bottom of each shoe. The clearance should be about paper thickness, i.e. $\frac{1}{64}$th and $\frac{1}{100}$th inch. Now lock each heel screw and check to see that the brake drum is still just clear of the lining. Next adjust the air gap $C$ between the armature and the solenoid by means of the adjusting screw $D$. The air gap should be reduced to a minimum by adjusting the screw $D$ so that while applying hand pressure to the armature, so that the brake shoes are hard against their stops, the armature is just clear of the solenoid. The clearance should be between $\frac{1}{100}$th and $\frac{1}{64}$th inch. This ensures the minimum possible air gap between the armature and yoke and hence the maximum effective pull from the solenoid. Spring pressure should now be applied by the adjusting screw $E$ until it is impossible to turn the lift motor with the winding handle in either direction, with the brake on. After removing the winding handle and switching on, the lift should be run and tested for smooth stopping and accuracy of levelling. The final position of the screw $E$ depends upon the particular stopping characteristics required. For a permanent adjustment, the brake lining must be well bedded in and the drum have a smooth, highly-polished surface. If the coefficient of friction of the linings is too high, the final stopping may be jerky; this is sometimes overcome by using a special zinc-bonded lining in which the zinc acts as a permanent dry lubricant and reduces brake drag to a minimum.

The accuracy of the final levelling depends very largely on the brake adjustment but is also influenced by the speed of the lift at the instant of brake application. The slower this final speed the more accurate the levelling. In practice it is possible to level approximately within $\pm \frac{1}{2}$ in. from a levelling speed of 50 ft. per min., within $\pm \frac{1}{4}$ in. from 20 ft. per min., and within $\pm \frac{3}{16}$th in. from 10 ft. per min.

**A.C. versus D.C. Brakes.** The principles of design and operation of an a.c. brake are somewhat different from those of a brake intended for use on d.c. In the cases of two-speed a.c. motors, and of d.c. motors, the mechanical brake is assisted by the dynamic braking action, but single-speed a.c. motors do not lend themselves to dynamic braking, and consequently the whole of the braking force must be supplied by the mechanical brake which must, therefore, be greater in size. Further, since

the rotor of an a.c. machine is larger than that of a comparable d.c. machine, the brake in the former case must be still larger. The operation of a d.c. brake can be made very smooth by connecting a resistance in parallel with the coil, the resistance providing a path for the induced currents and allowing the flux variations to take place gradually. This resistance also prevents the puncturing of the insulation of the brake coil by any rise in pressure due to a supply interruption. It is not practicable, however, to use a parallel resistance with an a.c. brake, and the tendency is for the shoes to be applied more fiercely. A dashpot is often fitted to minimize the brake shock on application of the shoes. The magnet is, in addition, often immersed in oil so as to dissipate the heat developed in the coil and magnet. An oil-immersed a.c. brake is illustrated in Fig. 93, and an electro-hydraulic thrustor-operated a.c. brake in Fig. 94. The brake in Fig. 94 is operated by a compression spring in the base of the brake and released by energizing the electro-hydraulic thrustor which imparts a thrust to a lever from which it is transmitted to a rod and so releases the shoes from contact with the brake drum. Solid magnetic cores are employed in a d.c. brake, and laminated cores for a.c. brakes in order that the eddy-current losses in the latter type shall be kept to a minimum. Fig. 95 shows a contactor type a.c. brake with laminated core. Silence is another point in favour of the d.c. brake, although hum from a.c. brakes can be considerably reduced by employing copper loops in the

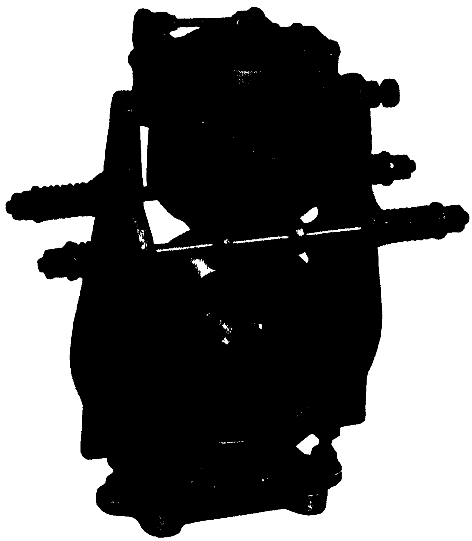


FIG. 93. OIL-IMMERSED A.C. BRAKE
*(R. J. Shaw & Co.)*

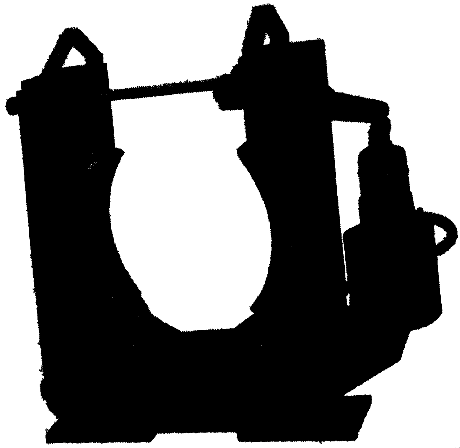


FIG 94 THRUSTOR OPERATED ELECTRO HYDRAULIC A C BRAKE
(Dewhurst & Partner Ltd)

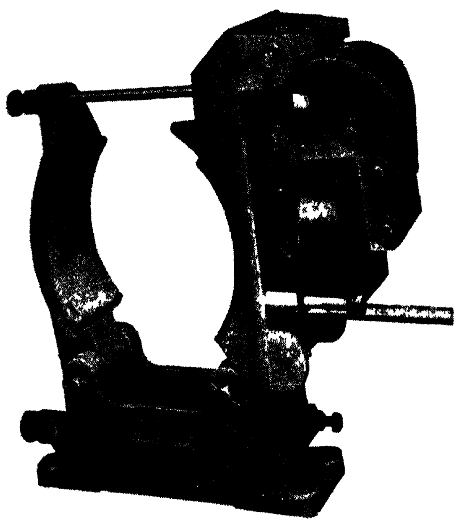


FIG 95. CONTACTOR TYPE A C BRAKE
(Dewhurst & Partner Ltd)

faces of the magnet cores. The current induced in the loop causes the shaded pole flux to be reduced and to lag behind the main flux, and this results in a more even brake pull. Other differences between the two types of brake are, that whilst the d.c. brake takes the same current regardless of position of the shoes, the a.c. brake takes a much larger current when

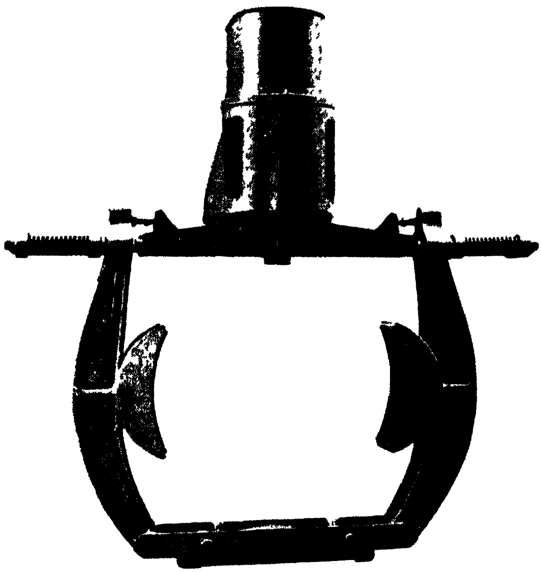


FIG. 96. GEARLESS MACHINE D.C. BRAKE
(*Wm. Wadsworth & Sons*)

the air gap is large than when it is small; and although the pull in the case of the a.c. magnet is nearly constant throughout the travel of the solenoid plunger, in a d.c. magnet the pull is approximately inversely proportional to the square of the air gap. On account of the difficulties associated with a.c. brakes most makers prefer to install d.c. brakes regardless of the nature of the supply, and when this is a.c. the brake supply is obtained from a rectifier.

For gearless d.c. machines the brake must be of larger size because of the absence of gearing. So far as rotor kinetic energy

is concerned, however, although the rotor is much larger, it runs at a considerably reduced speed. An important factor in the design of gearless motor brakes is the time constant, which should be of such a value that a squeezing action results rather than a direct impact. Its torque should be sufficient to hold $1\frac{1}{4}$ times the contract load in the car. A brake for a gearless d.c. machine is illustrated in Fig. 96.

# CHAPTER VIII

## GEARING

If we assume that a typical lift has a lifting rope diameter of ⅝ in., a sheave diameter of 50 rope diameters, i e. 32 in., and a car speed of 200 ft. per min., then the speed of a suitable motor for a direct drive installation will be about 24 r.p.m. The slow-speed gearless motor, however, is only practicable

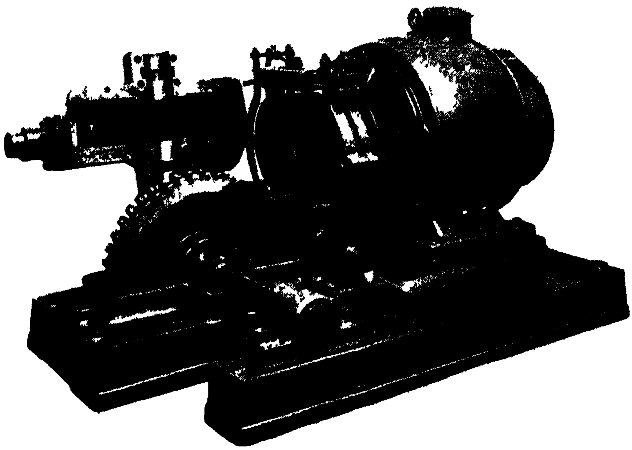


Fig. 97. Lift Gearing
(Worm and cover raised)
(*Marryat & Scott*)

for speeds above about 350 ft. per min., and for speeds slower than this a general purpose motor running at about 1 000 r.p.m. is used. Hence, with a motor of the latter type, it is necessary to use some form of gearing, the ratio of which, in the above case, should be 42 to 1. In practice, the gear ratios employed vary between about 20 to 1 and 60 to 1. Whilst it is not possible to use the gearless drive for slow car speeds it is also impracticable to employ gearing for speeds much in

excess of 400 ft. per min. on account of difficulties in manufacture and in maintaining the thrust adjustment sufficiently accurate to ensure smooth operation. The type of gearing invariably adopted is the worm and worm-wheel, both members being totally enclosed in an oil-tight gearcase, a typical example of which is shown in Fig. 97. The worm may be either above or below the wheel, and there are probably as many of one type in use as the other. The former is termed the *over-type* gear, and the latter the *under-type*, each having its advantages. Over- and under-type geared machines are shown in Figs. 29 and 30 respectively. Advantages claimed for the over-type are that the low-speed load carrying shaft is lower down on the bedplate, the worm which suffers the most wear is capable of easy inspection, and it is not so difficult to maintain oil-tight joints in the gear casing. With the under-type gear, any wear in the main bearings allows the wheel to drop into closer mesh with the worm instead of drawing the gears apart, and, in addition, the lubrication is probably more complete, since the worm is always immersed in oil. Although, in the over-type gear, the worm is not immersed in oil, sufficient oil to provide ample lubrication is carried upwards by the worm-wheel teeth. The oil is thrown from the wheel and cooled during its passage down the gear case and back to the reservoir. The design of both types should be such that the temperature rise of the oil in the sump never exceeds 100° F. The worm-wheel is forced on to its shaft by hydraulic pressure and fixed by two keys at right angles to each other. Alternatively, the wheel may be bolted to one flange of a worm and sheave centre, the other flange being bolted to the sheave. The combined centre is pressed on to its shaft and the latter method therefore obviates the use of keys. Fig. 98 shows a worm-wheel,

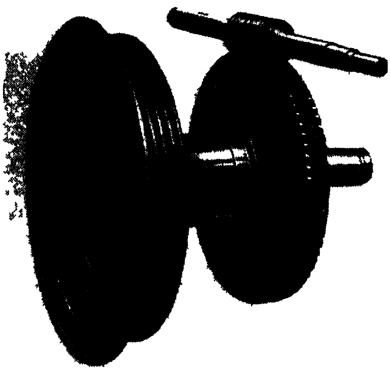


FIG. 98 WORM WHEEL AND WINDING SHEAVE, SHOWING KEYLESS ASSEMBLY
(*Wm Wadsworth & Sons*)

sheave, and the connecting spider which gives a keyless assembly. The hobbing of the worm-sheel after assembly, as shown in Fig. 99, ensures perfect concentricity of pitch line with journals. The worm shaft and the motor armature shaft are each secured to the brake drum by a key.

For a worm and worm-wheel drive the most satisfactory materials for the two members are steel and phosphor-bronze,

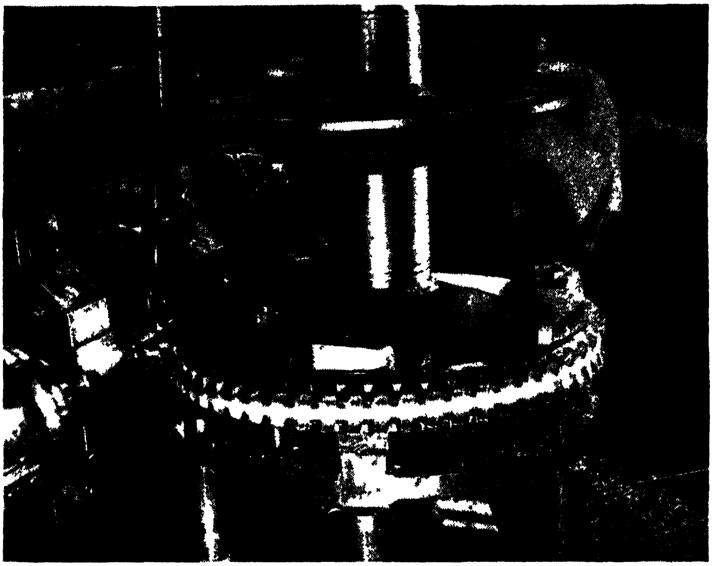


FIG. 99. HOBBING OF THE WORM-WHEEL
(*Express Lift Co. Ltd.*)

and these are used for the worm and worm-wheel of lift gearing. The worm is usually made of 5 per cent nickel steel or $3\frac{1}{2}$ per cent nickel chromium steel, forged solid with the shaft, polished and case hardened, although some lift makers prefer to use a 0·4 or 0·55 per cent carbon steel which is heat treated and not case hardened. The worm-wheel is of solid phosphor-bronze for small gears, but for the larger gears consists of a renewable phosphor-bronze rim and a cast-iron centre. The rim is sand casted or centrifugally casted and is either shrunk and fixed by grub screws or bolted to the centre: an example of

the latter method of fixing the worm-wheel rim being shown in Fig. 100. To ensure silent running, the gear teeth must be accurately hobbed. As a safety precaution, the angle of lead of the worm is sometimes made small, with a view to obtaining

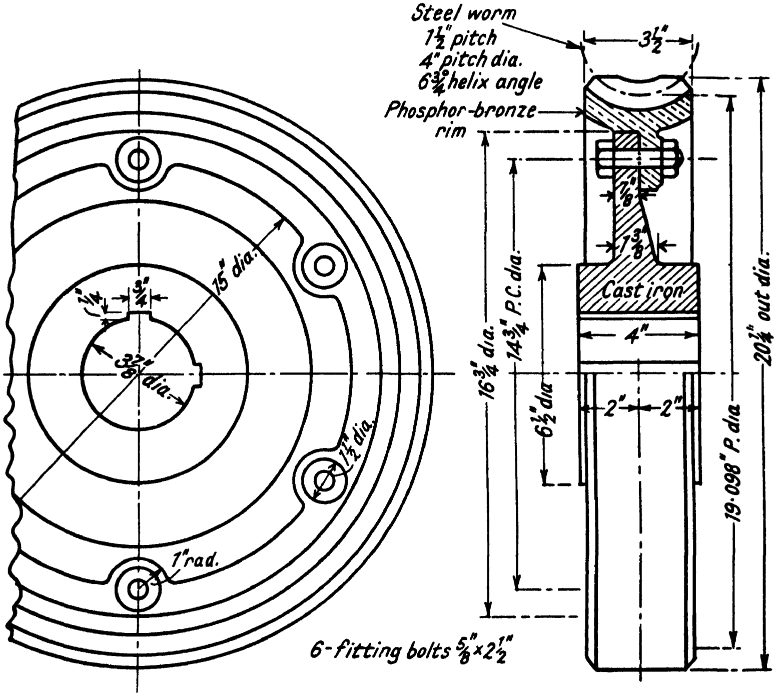



FIG. 100. PHOSPHOR-BRONZE WORM-WHEEL
40 teeth, 1½ in. pitch
(*R. J. Shaw & Co.*)

irreversibility of the gear; and the danger of the lift "running away," in the event of a brake failure, is therefore minimized. The h.p. rating of the gear should be calculated in accordance with B.S. 721 : 1937 which takes into account the wearing qualities and the strength of the teeth.

From details of the gear dimensions and materials it is possible to calculate the power capacity for wear of the worm and for wear of the wheel and also the power capacity for

strength of the worm and strength of the wheel. The smallest of these four values is the normal h.p. rating of the gear. This normal rating is the loading to which the gears may safely be subjected for a period of 12 hours per day. Where the loading on the teeth is not uniform throughout its duty cycle, as is the case with lift gears, it is necessary to calculate the value of the equivalent uniform load which, acting for 12 hours per day, would have the same effect on the gears. This entails a consideration of the load cycle of the gearing from the number and frequency of the journeys performed by the lift in 12 hours. From this duty cycle, the equivalent running time per day may be calculated. This will be some figure less than 12, and by multiplying the running-time correcting factor, as determined from B.S. 721 : 1937, by the maximum gear torque, the equivalent ratings for the actual duty for wear and strength may be calculated. These will be less than the normal h.p. ratings for wear and strength, and the smaller of the two is the equivalent rating of the gear. It is necessary to determine this equivalent rating depending on the lift duty, as a gear suitable for the normal rating (12-hour duty) will be unnecessarily large for the particular duty.

**Irreversibility.** This, perhaps, may be best understood by considering the following fundamental relations—

Efficiency (worm driving) $= \tan \lambda / \tan (\lambda + \phi)$ where $\lambda$ is the angle of lead of the worm and $\tan \phi$ is the coefficient of friction between the worm and wheel, corresponding to the rubbing speed employed. The coefficient of friction $\mu$ varies from 0·013 at 3 000 ft. per min. to 0·10 at 5 ft. per min. for phosphor bronze on steel.*

The efficiency is a maximum when $\lambda = (45° - \frac{1}{2}\phi)$ and a minimum when $\lambda = 0°$ and $(90° - \phi)$.

Graphs showing the relations between efficiency and $\lambda$ for various values of $\mu$ are shown in Fig. 101.

Reversed efficiency (wheel driving) $= \tan (\lambda - \phi) / \tan \lambda$.

The worm gear is irreversible if the reversed efficiency is zero or negative. This is the case when $\lambda$ is equal to or less than the angle of friction $\phi$. For irreversibility the efficiency cannot

* B.S. No. 721: 1937, *Machine Cut Gears—Worm Gearing.*

be more than 50 per cent, and from the graphs it will be seen that it may be considerably less. Further, it will be noted that $\lambda$ must be small, particularly with high efficiency gearing.

The angle of friction, however, changes rapidly with the rubbing speed, and the static angle of friction may be reduced

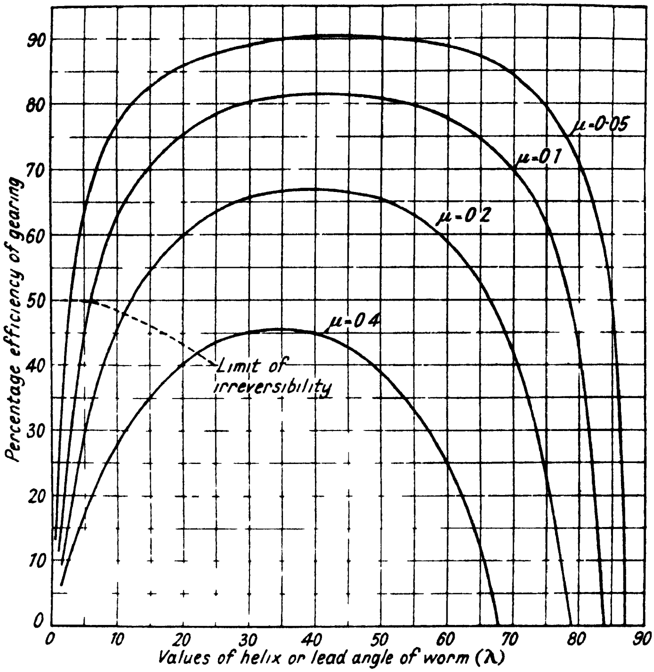



FIG. 101. GRAPHS SHOWING RELATION BETWEEN EFFICIENCY AND ANGLES OF LEAD OF WORM FOR VARIOUS VALUES OF $\mu$

by external vibration. The design of irreversible worm gear is therefore always accompanied by an element of uncertainty, and it is recommended that to obtain complete security some form of brake be employed. High efficiency gearing is often used on modern lifts, and any degree of irreversibility of the gearing is thus sacrificed in favour of higher efficiency. The possibility of the lift "running away," however, is guarded against by fitting an overspeed governor.

**Thrust Races.** The movement of the car up and down the

well transmits thrusts in both directions of the worm axis and means must be provided to cater for these thrusts. Single ball thrust races are sometimes fitted at each end of the worm shaft, but more usually a double ball thrust as depicted in Fig. 102 is provided at the outer end of the shaft, the thrust race being capable of adjustment as wear takes place. In the illustration

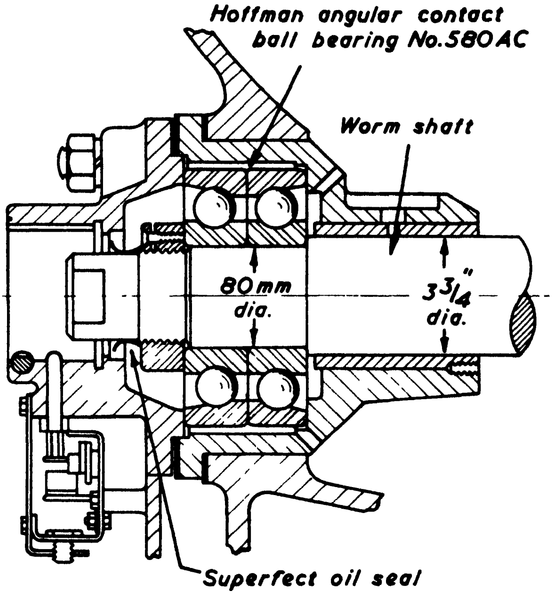



FIG. 102. DOUBLE BALL THRUST

two angular contact ball bearings are shown, each bearing being capable of carrying radial load and thrust load in one direction.

**Tandem Gearing.** For heavy duty, tandem gearing, consisting of two worms and two wheels, is sometimes employed, the worms being respectively left- and right-handed. The worm-wheels are meshed together as well as the worms and wheels. With this type of gearing, the worm is subjected to two equal and opposite thrusts, and separate thrust bearings are therefore unnecessary.

**Spur Gearing.** This is sometimes used, in addition to a worm reduction gear, for handling heavy loads at slow speeds. A

double-geared machine of this type is shown in Fig. 103 and consists of the usual worm-geared machine with the addition

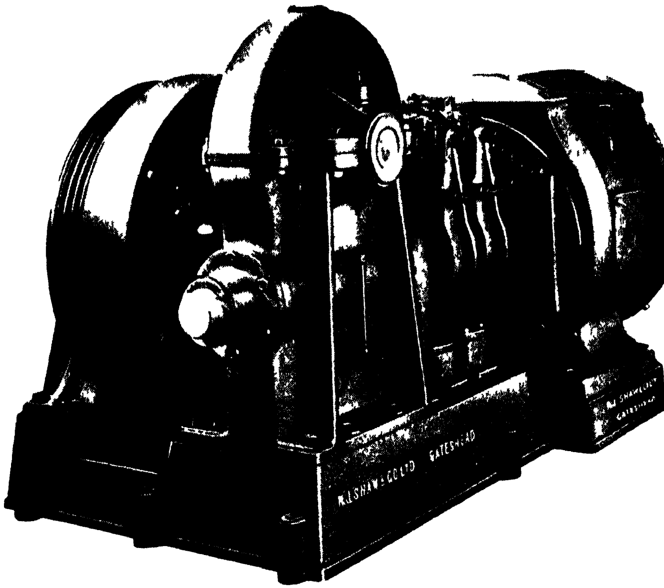


FIG. 103. DOUBLE-GEARED HEAVY DUTY LIFT MACHINE
(*R. J. Shaw & Co.*)

of an internal spur reduction gearing. The machine shown is capable of lifting 3 tons at a speed of 100 ft. per min., and is fitted with twin oil-immersed brakes for operation from alternating current.

# CHAPTER IX

## CARS, COUNTERWEIGHTS, AND GUIDES

**Passenger Cars.** The number of passenger car designs is unlimited; the car can be made to almost any specification, the actual finish being usually left to the purchaser. There are a few items of design, however, which should be incorporated in all modern lift cars. The clear height should be at least 6 ft. 6 in., and usually is about 7 ft. 0 in. or even more. A load plate showing the contract load should be fitted in each car. An alarm bell or a telephone should be provided, to enable a call for assistance to be made in case of breakdown or failure between floors. Where only one lift operates in a well, a hinged panel opening outwards should be fitted in the roof, as a means of exit in cases of emergency. This exit should be not less than 18 in. by 24 in. If more than one car operates in a well, side exits are sometimes provided, and these are either removable panels or doors opening inwards. These side exits enable the transference of passengers from one car to another. All emergency exits should be fitted with an electric interlock which will prevent the lift from being operated if an exit is left open. Means should also be provided in the roof adequately to ventilate the car, particularly if solid car doors are used, whilst artificial lighting is also necessary, and for this almost any form of fitting may be used. Very effective lighting can be obtained by means of tubular fittings at each of the four corners, or by laylights. A car roof unit with combined 9-in. fan and light fitting is shown in Fig. 104. The air from the fan is directed into the car through louvres fitted around the light.

Lift cars consist of two separate units, namely the *sling* and the *car*, the former being constructed of bolted or welded rolled steel angle or channel sections and must be sufficiently rigid to withstand the operation of the safety gear without permanent distortion. A typical car sling is shown in Fig. 105. The side frames are built up of steel angles with gusset plates riveted to each corner, and vertical or diagonal stays to give extra strength and stiffness. The main suspension crosshead is

fixed to the top of the frame, and to this is bolted the housing for the two spring-loaded top guide shoes, whilst the bottom sections carry the car safety gear and the remaining two bottom guide shoes. The crosshead and the bottom platform sections should not deflect more than $\frac{1}{1000}$ of their span with the contract load in the car. The lifting ropes are attached to the top crosshead.

The usual type of guide shoe is of phosphor-bronze or cast

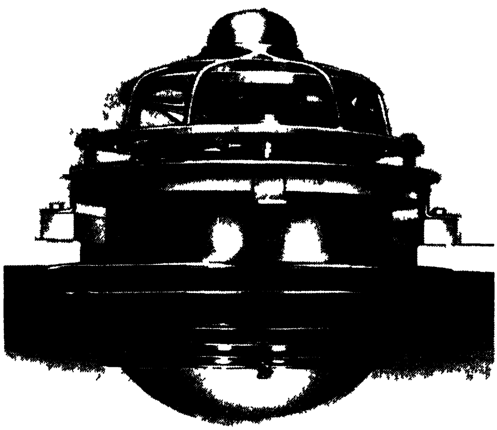


FIG. 104. COMBINED FAN AND LIGHT FITTING.
*(Express Lift Co. Ltd.)*

iron about 9 in. long and shaped to fit the guide, typical examples being shown in Figs. 106 and 127.

Roller shoes, which have been used extensively in America, have been employed in recent years in this country. These comprise three rubber-tyred spring-loaded rollers, one operating on the head of the guide and the other two on the sides. These transform the lift from a sliding motion to that of a rolling vehicle. The car thus tends to float between the guides and friction is thereby considerably reduced. These rollers, mounted on ball bearings, operate on dry unlubricated guides and there is thus no accumulation of grease on the guides or in the lift well. Each roller is supported by a pivoted rocker-arm which

automatically adjusts itself to the guide. A roller guide shoe of this type is shown in Fig. 107.

FIG. 105 CAR FRAME AND SAFETY GEAR
(*Marryat & Scott*)

The car is rigidly fixed to the sling in such a manner that unequal loading on the floor cannot throw undue weight on the cabinet work In modern high-grade cars it is sometimes the

practice to insulate the car from the frame and so prevent vibration from the ropes and the guide shoes being transmitted to the passengers. In the Waygood-Otis passenger car the entire lift car, including the platform, rests on eight "live" rubber blocks mounted on a steel supporting structure. Lateral and upwards motion of the car is restrained by "locking" blocks, but there is no metal to metal connexion between the

FIG. 106. GUIDE SHOE
*(Marryat & Scott)*

car and the frame. The top of the car is held firmly to the upright members of the car frame by rubber-faced clamps that are welded to each side of the car's canopy. In addition, the side panels are coated on the outside with a layer of bituminous sound-deadening compound which absorbs the noise of passing air and prevents amplification of sounds originating in the car.

The floor is made of well-seasoned wood, usually maple, and frequently iron tongues are let in between the planks to afford

extra strength. Linoleum, rubber, or parquet, finished in any design to blend with the remainder of the car, may be used as the floor covering. The car back and side framings are often of 1½ in. teak, oak, mahogany or walnut, with panelling of about ¾ in. to match, whilst ornamental pilasters or corner posts may also be incorporated, but no glass should be used in the roof or in the car enclosure except for lighting fittings or a door vision

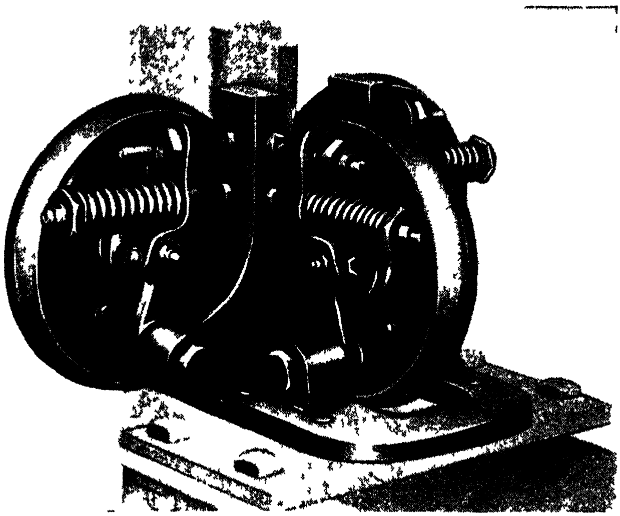


FIG 107 ROLLER GUIDE SHOE
(*Waygood-Otis, Ltd*)

panel of the shatter-proof type. Alternatively, a painted or enamelled finish or padded leather sides and back are sometimes adopted; also, laminated boards lined with rubber, the joints being covered with metal strips. Cars lined with Formica are now popular. This material is made in many finishes, is durable and not easily defaced. Occasionally, seats are required, whilst a kicking plate about 9 in. deep and of bronze or stainless steel is frequently fitted. Fig. 108 shows a kicking plate in a two-entrance car, and Fig. 109 a car in Formica, designed for use in tropical climates: in addition to being well ventilated, this is fitted with an electric fan. All-metal cars are becoming popular, and these, too, may be obtained with, or without,

ornamental strips, and in almost any design and colour of lacquer finish An example of an all-metal car is shown in Fig. 110. This has a cellulose finish, two-speed steel sliding doors

FIG 108 PASSENGER CAR
(*Wm Wadsworth & Sons*)

and tubular fluorescent lighting Fig 111 is another attractive modern all-metal car finished in cellulose.

**Car Floor Area.** In calculating the floor area necessary, the figure of 2 sq ft per person gives a close approximation for

contract loads up to 1 500 lb., i.e. 10 persons. As the load increases beyond 1 500 lb., however, the area per person decreases. For example with 20 persons, 33 sq. ft. is required and with

FIG. 109. CAR SUITABLE FOR TROPICAL CLIMATES
*(Marryat & Scott)*

30 persons only 46 sq. ft of floor is necessary The contract load for a passenger lift may be calculated from the following formula—

$$L = 60a + 70a\left(1 - \frac{1}{e^{0\cdot0166a}}\right)$$

where

$L$ = minimum contract load in lbs. $e = 2{\cdot}718$.

$a$ = effective platform area in sq. ft. This relation between $L$ and $a$ is shown in the curve in Fig. 112.

**Goods Cars.** The sling is of similar construction to that adopted for passenger cars but the car itself is of much rougher construction. The floor is made of double planks at right angles,

FIG. 110. ALL-METAL CAR
(*Marryat & Scott*)

the top layer being made of well-seasoned maple planks about 5 in. wide and 2 in. thick, and the bottom layer of 2 in. deal, whilst the sides, back, and top are of 1 in. tongued and grooved pitch pine. Wire mesh is sometimes used for the car top instead of wood. A typical goods car is shown in Fig. 113, the sides being of tongued and grooved varnished pine and the floor double-boarded at right angles, the top layer of maple. The sides and back are often lined to a height of about 3 ft. with sheet steel $\frac{1}{8}$ in. thick. All-steel cars are frequently used for the transport of heavy or rough materials, the sides being

constructed of sheet steel or expanded metal, and the floor of steel chequer plate. An all-steel goods car with chequer plate floor and fire-resisting steel shutter door is shown in Fig. 114

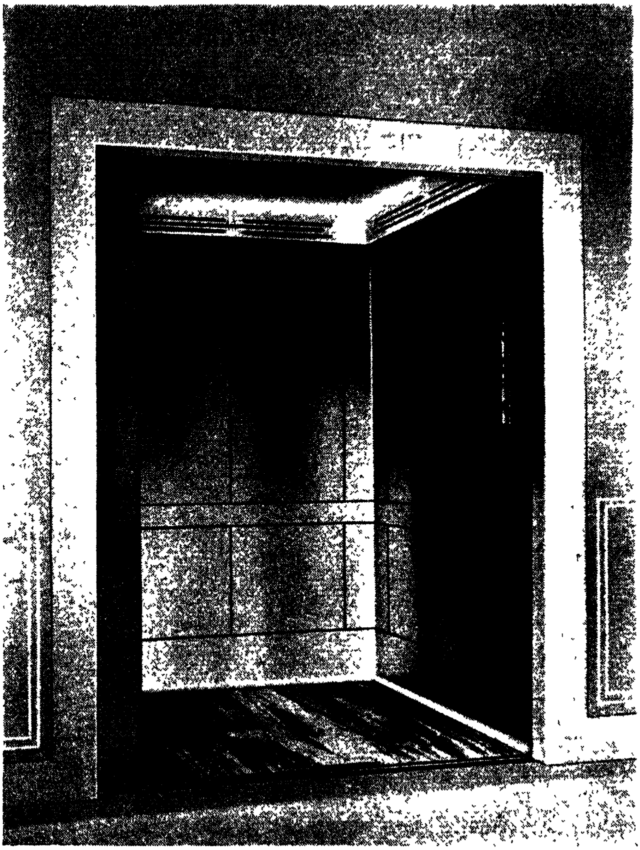


FIG. 111. PASSENGER CAR
(*Wm. Wadsworth & Sons*)

and a panelled steel goods car with collapsible gates in Fig. 115. In both of these cars it will be noted that the entrance is the full car width. With passenger or goods cars it is good practice to have a plate fitted to the crosshead and engraved to show the weight of the complete car with fittings, the contract speed, and

the strength, size and construction of the hoisting ropes. The minimum contract load for goods lifts shall be based on a load of not less than 70 lb. per sq. ft. of car floor area.

**Car Travelling Cable.** All electrical connexions to the car are made by means of a multi-core hanging flexible cable, one end

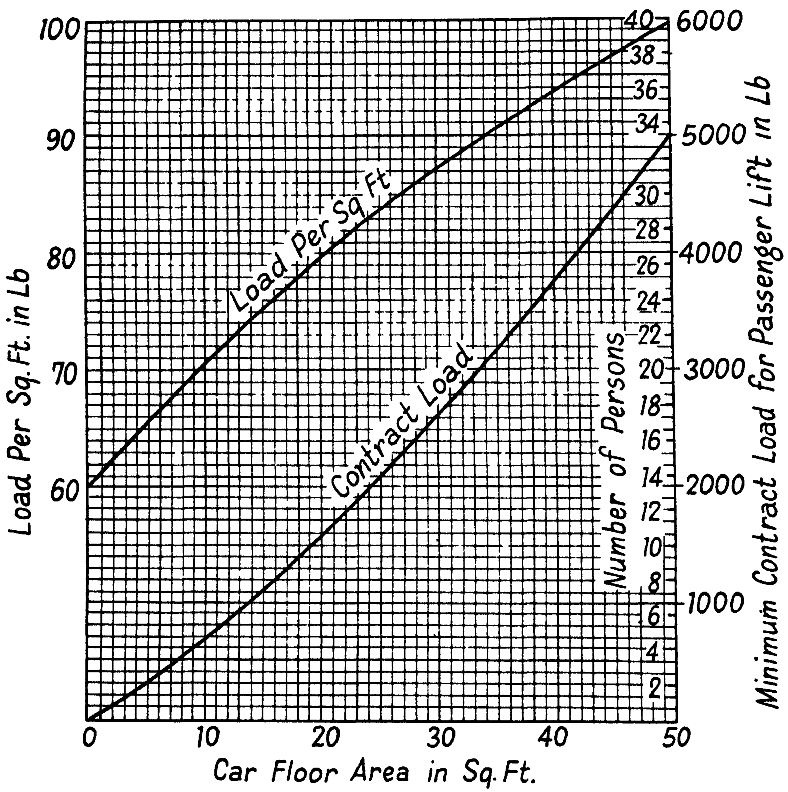



FIG. 112. CURVES SHOWING THE RELATIONS BETWEEN LOAD, LOAD PER SQ. FT. AND CAR FLOOR AREA

of which is connected to a terminal box fitted under the car floor, the other to a terminal box fitted in the well at approximately the mid position. These travelling cables should fulfil the requirements of B.S. 977 : 1941. All car connexions from the controller are run to the well terminal box. The length

of the flexible cable should be approximately equal to half the lift total travel plus 15 ft. so that the car may travel from end to end of the well without subjecting the cable to any strain.

## COUNTERWEIGHTS

The object of the counterweight is to balance the weight of the car plus a predetermined proportion, usually 40 to 50 per

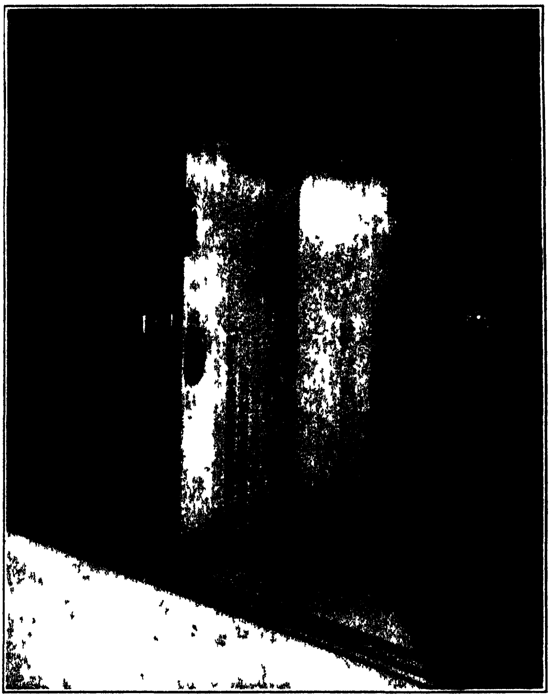


FIG. 113. GOODS CAR
(*Wm Wadsworth & Sons*)

cent, of the maximum car load, and thereby to reduce the size of the motor. Incidentally, the counterweight provides a certain measure of safety. The most usual construction consists of cast-iron sections firmly secured against movement by at least two steel tie rods having lock nuts or split pins at each end, and

passing through each section, as shown in Fig. 116. In addition to tie rods, the sections are sometimes mounted in a steel framework as in Fig. 117. For heavy loads the sections are sometimes weighted with lead so as to reduce the size of the counterweight. The hoisting ropes may be secured to the

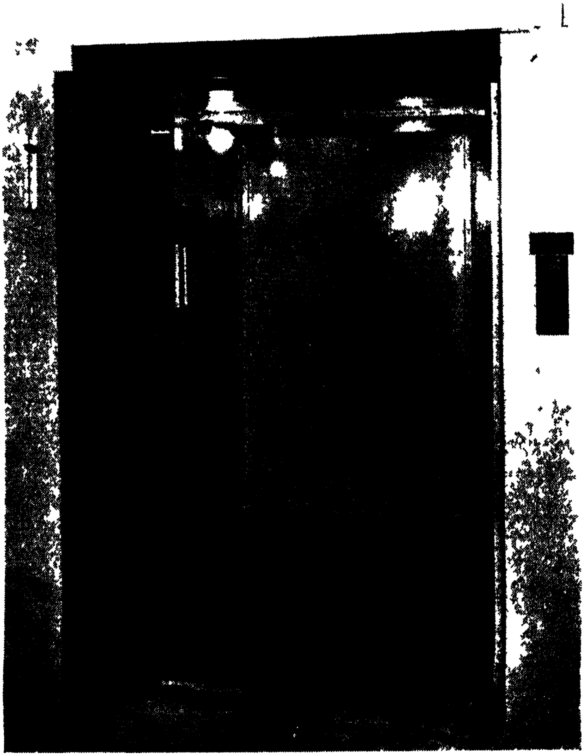


FIG. 114 ALL STEEL GOODS CAR
*(Marryat & Scott)*

counterweight top frame by eyebolts which allow of rope adjustment, by splices or clips. Four spring-loaded shoes, similar to those for the car, are fitted to ensure that the counterweight will travel smoothly in its guides. Safety gear is sometimes fitted and may be either of the types mentioned in Chapter XII.

## GUIDES

Some form of guiding is necessary for both the car and counterweight so that they will travel in a uniformly vertical

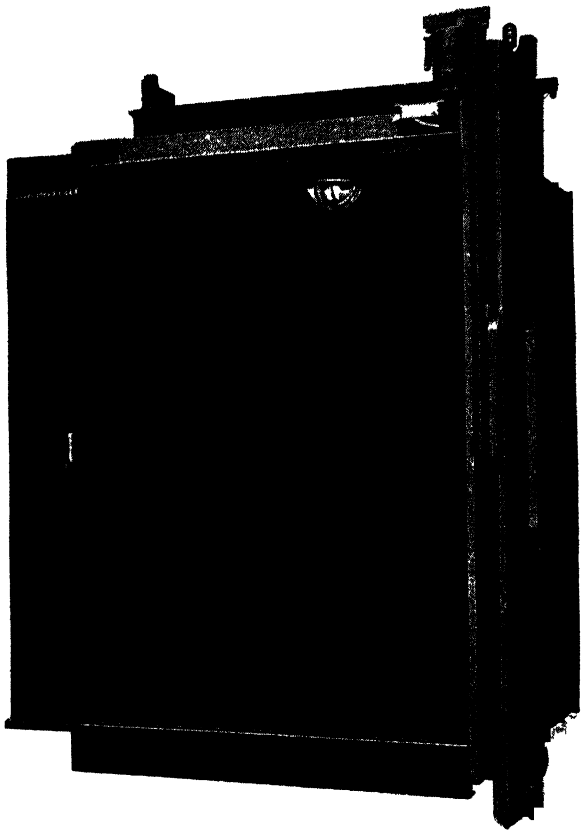


FIG. 115. PANELLED STEEL GOODS CAR
(*Express Lift Co. Ltd*)

direction. The guides must be of such lengths that it will be impossible for any of the car or counterweight shoes to run off the guides. In the most common arrangement, two guides are required for the car and two for the counterweight, but

the actual number and the relative positions of the guides depend upon the landing openings required. Openings all on one side of the well permit of the simplest guide arrangement; the counterweight guides are fixed to the wall opposite the landings, and the car guides, one on each of the two remaining walls. In some instances it is necessary to cater for landing openings on opposite sides of the well, and in these cases a car guide is supported on each of the two remaining walls and both counterweight guides on one of these walls. Openings on adjacent sides or even on three sides are sometimes required, and this involves guiding the car diagonally at two of its corners, or alternatively at each of the four corners. In the case of this corner guiding, the car frame is cut away at the corners so as to provide fixings for the guide shoes. A three-point guiding is sometimes adopted for cars with adjacent openings, and in this arrangement two guides are placed, one at each corner of one side, with the third guide at the middle of the opposite side.

**Material.** Well-seasoned teak and rolled steel channel have been extensively used for car and counter-weight guides, but modern practice favours either round steel or tee-section steel guides for speeds exceeding 100 ft. per min. except where the nature of the work carried on in the building renders steel unsuitable, due to acid fumes, when specially prepared wooden guides are installed. Tee-section guides are the latest practice, and are now recommended for both car and counterweight on all lifts travelling at speeds in excess of 200 ft. per min. The advantages of tee-section guides are, that there is no tendency for the shoes to get out of place, as is possible with round steel guides; they afford a larger shoe bearing surface, and result in more even shoe wear. Further, this type of guide is sufficiently rigid to make the use of guide backings unnecessary.

**Sizes.** Three standard sizes of Tee guides are manufactured by British Guide Rails, and these together with data on each type are listed in Fig. 118. For comparison purposes corresponding information for round-section steel guides used for lifts is also quoted. Tee guides are being used in increasing numbers and are now rapidly replacing round guides. These Tees are straightened before being machined and when finished are guaranteed to be straight to within limits of 0·002 in. The stock length is 16 ft. As the deflection of a guide due to a

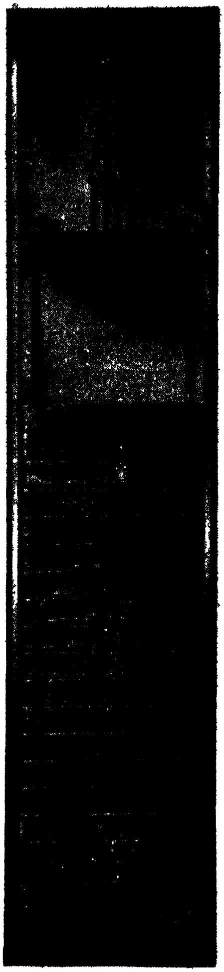


FIG. 116. COUNTERWEIGHT
(*Marryat & Scott*)

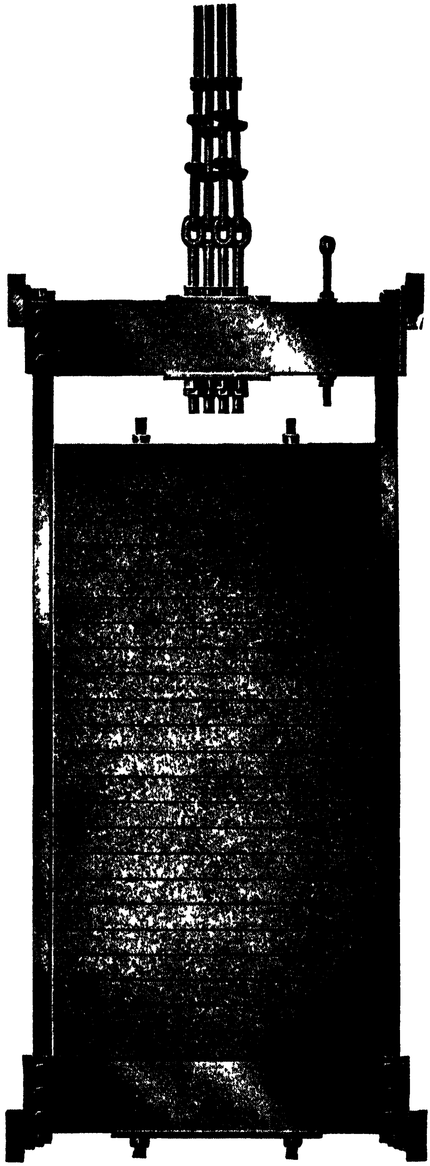
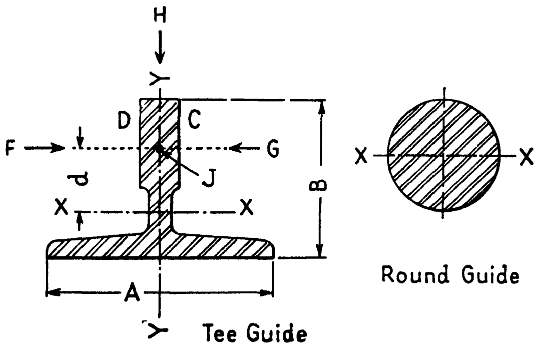


FIG. 117. COUNTERWEIGHT
(*Express Lift Co. Ltd.*)

load is inversely proportional to the moment of inertia of its section it will be noted from the table that T160, T161 and




| Steel Tees No | Size A (In) × B (In) | Weight Lb per Ft | Area Sq In | IXX $(In)^4$ | IYY $(In)^4$ |
|---|---|---|---|---|---|
| T163 | $2\frac{3}{4} \times 1\frac{15}{16}$ | 6·25 | 1·79 | 0·75 | 0·62 |
| T161 | $3\frac{1}{2} \times 2\frac{7}{16}$ | 8·0 | 2·41 | 1·4 | 1·28 |
| T160 | $5 \times 3\frac{1}{2}$ | 14·87 | 4·417 | 4·75 | 5 93 |
| | | | | | |
| Steel Rounds | $1\frac{1}{2}$ Dia | 6·008 | 1·767 | 0·248 | |
| ” | $1\frac{3}{4}$ ” | 8·170 | 2 405 | 0·460 | |
| ” | 2 ” | 10·68 | 3·141 | 0·785 | |
| ” | $2\frac{1}{4}$ ” | 13·52 | 3·976 | 1·258 | |
| ” | $2\frac{3}{8}$ ” | 15·06 | 4·430 | 1·562 | |
| ” | $2\frac{1}{2}$ ” | 16·69 | 4·908 | 1·917 | |
| ” | $2\frac{3}{4}$ ” | 20·19 | 5·939 | 2·807 | |
| ” | 3 ” | 24·03 | 7·068 | 3·976 | |
| ” | $3\frac{1}{4}$ ” | 28·21 | 8·295 | 5·476 | |

FIG. 118. DATA RELATING TO TEE GUIDES AND ROUND GUIDES

T163 guides are approximately equivalent to 3 in., $2\frac{3}{8}$ in. and 2 in. diameter round steel guides. Hence there is a considerable saving in steel by using Tee guides. The relative strengths of

Tee and round guides is illustrated in Fig. 119 which shows deflection curves for guide fixings at various spacings, about the two principal axes of a T161 guide, about a diameter of a round guide of approximately the same weight ($1\frac{3}{4}$ in. dia.) and about a diameter of a round guide of approx. the same strength ($2\frac{3}{8}$ in. dia.). A guide length between two clips has been considered and for this purpose it has been assumed that

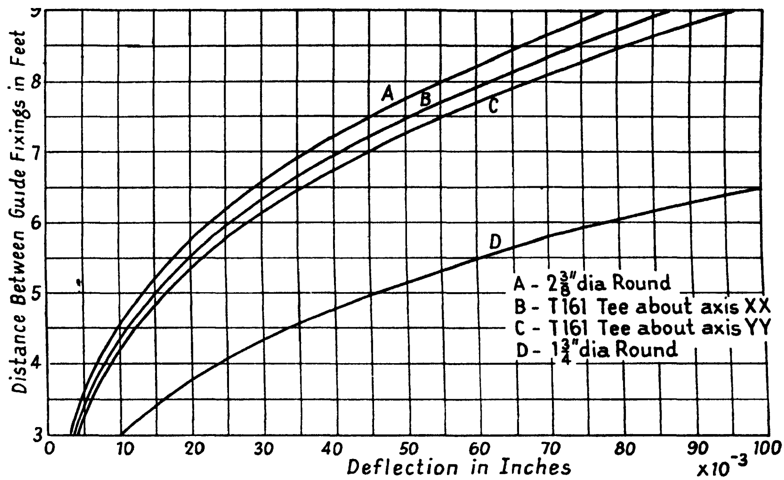



FIG. 119. GUIDE DEFLECTIONS FOR VARIOUS CLAMP SPACINGS

there is a shoe pressure on the guide of 0·25 ton when the shoe is midway between two clips. As these clips fix the directions of the ends of each section, the length between the clips has been treated as a beam with fixed ends, and the formula $\frac{WL^3}{192EI}$ has been used.

**Guide Stresses.** During the normal travel of an empty car the thrusts of the shoes on the guides are negligible if the car is of a balanced construction and is centrally slung. Also, if the car is loaded in such a manner that the load is uniformly distributed or centrally placed on the car floor no appreciable thrusts will be imposed on the guides. A concentrated load in the car located at some point other than the floor centre, however, will cause thrusts on the guides in the direction *F*, *G* or *H* (Fig. 118), depending upon the position of the load.

When the car is at a landing and is being loaded the weight of the load on the front edge of the car platform results in a guide thrust in the direction *F* or *G*. These thrusts may be of a high value if the load is concentrated and particularly if the car is very deep. Heavy loads are thus imposed on the guides if automobiles or laden trucks are run into the car. To withstand such heavy thrusts it is advisable that guide clamps be fitted opposite the guide shoes when the car is level with the landing. The thrusts are thus transferred to these fastenings but if they are not securely made the clips may be loosened. When the car is at a landing and the guide fixings are not opposite the car shoes the loading thrusts on the guides cause a guide deflection which will be greatest if the shoe is midway between two clips. The amount of this deflection will depend upon the guide section, the distance between fixings, the size and weight of the car and on the car load. If the car is large and heavy concentrated loads are handled it is necessary to consider backing or bracketing the guides and adopting close-spaced fixings to prevent the deflection being excessive. Such deflection caused during loading or by the load being off-centre in the car, should not exceed $\frac{1}{4}$ in. The opening of a heavy car gate or side-opening car door will cause a side load and result in guide forces in the direction *H* but these are not usually of appreciable magnitude. During normal operation the thrusts and consequent deflections on the counterweight guides are negligible.

In addition to the normal stresses outlined above, considerable loads are imposed on the guides when the safety gear is brought into operation, the magnitude of the resultant stresses depending upon the contract load and speed and the type of safety gear fitted. Referring to Fig. 118, the safety jaws grip the guides on the working faces *C* and *D* and this may be considered equivalent to a downward load imposed on the guide section at the point *J*. This is an eccentric load acting at a distance *d* from the centre of the section and results not only in a direct compressive stress but also in a bending moment of value equal to the retarding force multiplied by the distance *d*. The compressive force is transmitted to the guide end in the pit and hence the desirability of resting the guide end on a soleplate in order to distribute this load. The bending

moment results in guide deflection about the axis *XX*, i.e. guide spreading, the deflection being proportional to the resultant safety gear force, the modulus of the guide section and the distance between the guide clips. This bending moment also causes a tensile stress in the guide clamp fixing bolts. In addition, the forces imposed on these fixings due to the normal operation of the lift described above also result in a tensile stress in the clamp bolts. It is, therefore, important to ensure that the clamp fixings are strong enough to withstand these stresses. In practice the diameter of the steel clamp bolts should be not less than ½ in. for T163 guides and not less than ⅝ in. for T160 and T161 guides. The resultant safety gear force at *J* is considerable, particularly if the safety gear is of the instantaneous type. For example, if a car with its load weighs one ton and is fitted with instantaneous gear which operates at a car speed of 200 ft. per minute a sudden downward load of several tons will be imposed on each guide. The guide section must be adequate to limit both the compressive stress and the deflection to reasonable values. Gradual wedge-clamp or wedge-clamp safety gear slows the car more gradually and thus the retiring force is much smaller. For this reason instantaneous safety gears are not used for speeds above 200 ft. per minute, and some authorities limit their use to 100 ft. per minute and even then to small lifts only.

It will be appreciated from the above that considerable care is necessary in the selection of suitable guides and clip fixings for any particular type of lift. Except in special circumstances it is good practice to use T163, T161 and T160 guides with cars of maximum contract loads of 1 000 lb., 2 500 lb. and 10 000 lb., respectively. If counterweight safety gear is fitted the size of the counterweight guides should be the same as those for the car. Where counterweight safety gear is not provided, the counterweight guides have to withstand much smaller stresses than the car guides and, therefore, may be of smaller size. In such cases T163 is suitable for counterweights of lifts of contract loads up to 2 500 lb. and T161 where the contract load is as high as 10 000 lb. A guide clamp spacing of 10 ft. is common practice, but if concentrated loads are handled or the contract speed is high it is advisable to use a spacing of 8 ft. or even 6 ft.

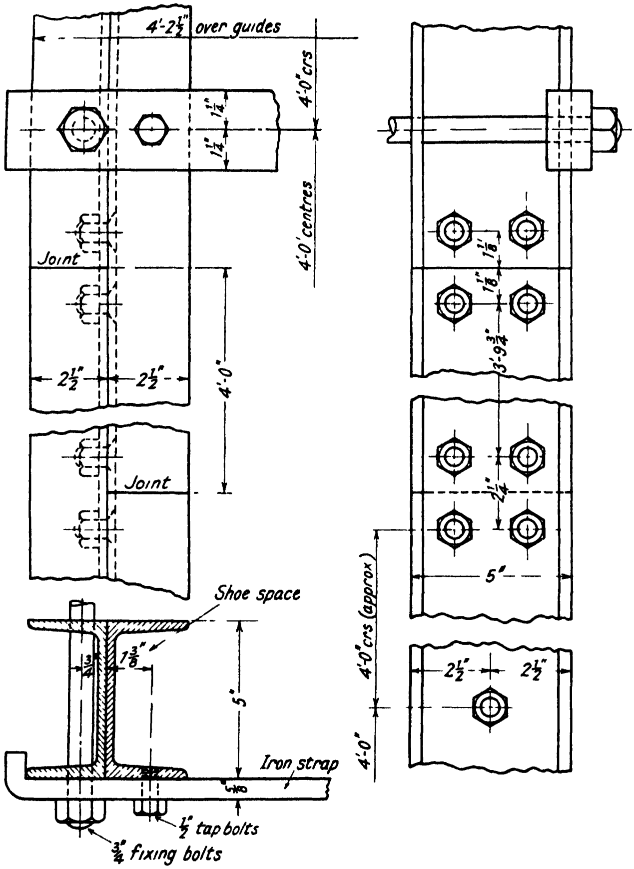



**Fig. 120. Method of Fixing and Jointing Channel Iron Guides**
*(R. J. Shaw & Co.)*

**Fixing and Jointing.** The method of fixing the guides depends upon the construction of the well and the relative positions of the car and counterweight guides, but the number of fixings should be such that the guides will not deflect more than $\frac{1}{8}$ in. under normal operation. In a staircase well or a self-contained steel structure the guides are fixed by plates and bolts with the additional provision of steel stringers if necessary. In a bricked well, the guides are secured either by Lewis bolts or by bolts passing through the brickwork and fastened on the outer sides by steel plates. The former method is frequently adopted for

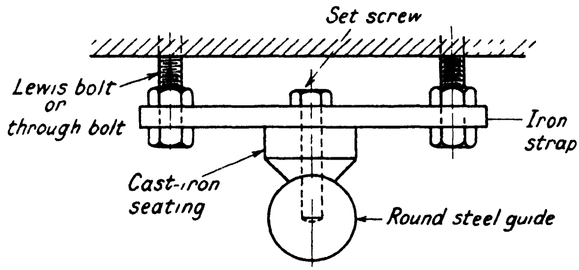



FIG. 121. ROUND GUIDE FIXINGS

outside walls and the latter for inside walls. In either case, a sound fixing in which all the shims are of metal is necessary, and when Lewis bolts are employed they should be sunk in the wall at least 6 in. and firmly bedded. At their bottom ends, the guides are sunk into the well for about 9 in. and concreted.

Fig. 120 shows the method of fixing and jointing channel iron guides for counterweights. This form of guide is sometimes used for counterweights of slow speed goods lifts. Each guide consists of two channels bolted together, the counterweight shoe travelling in the space formed by the web and two flanges of one of the channels. The various lengths, in each half of the guide, are arranged so that the joints are spaced at intervals of 4 ft., the jointing being carried out by four countersunk bolts passing through the web of each channel. The channels are, in addition, screwed to each other by single countersunk bolts at 4 ft. spacing. The iron strap is bolted to each guide at intervals of 4 ft. throughout the entire length of the guides. These straps are secured to each guide by a tapped bolt and a

through bolt, the latter serving as the fixing to the well and therefore may be either a Lewis bolt or a through bolt fixed at the outer side by a steel plate.

A method of fixing round guides is shown in Fig. 121 in which

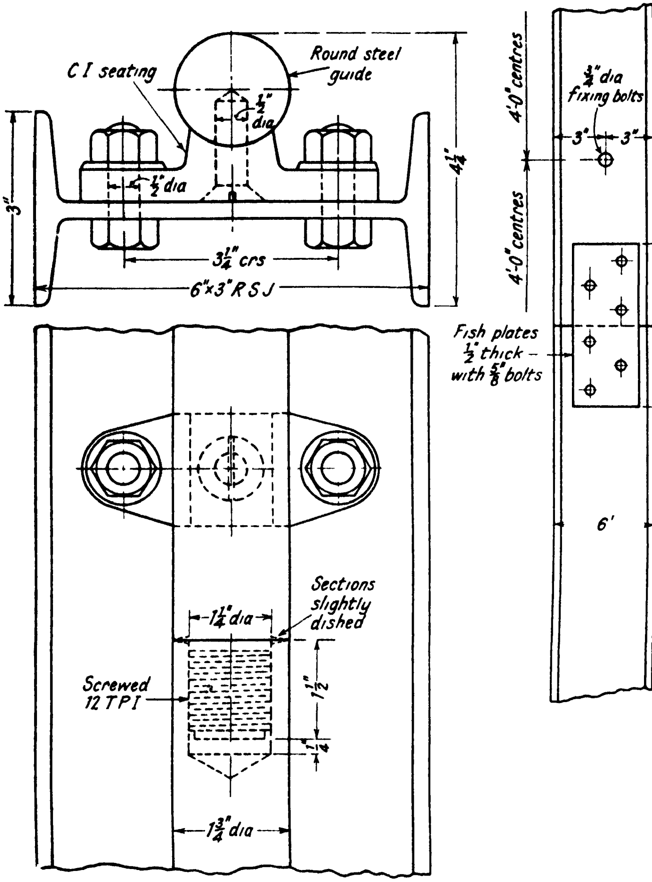



Fig. 122. Methods of Fixing and Jointing Round Steel Guide and Backing

(*R. J. Shaw & Co.*)

the guide is secured at intervals of 4 ft. to cast-iron seatings, these being screwed to iron straps. The latter are fixed to the well by Lewis bolts or through bolts.

Fig. 122 shows a method of fixing round steel guides in which rolled steel backings are employed. These backings avoid the necessity of using large section guides in order to secure rigidity, and also enable the safety gear to operate on the backings, as shown in Fig. 123, instead of on the polished guides. The guide is fixed to cast-iron seatings by countersunk screws, these seatings in turn being bolted to the backings. The various lengths of guide are jointed by screwed socket joints, whilst the lengths of backings are jointed by steel fishplates. A spacing of about 4 ft. is adopted for the bolts which secure the backings to the well.

Many different methods are employed for fixing tee-section guides, some of these being illustrated in Figs. 124 and 126. Fig. 124 shows the method of jointing tee-guides and of fixing the car guides to the well. The lengths of guide are jointed by machined spigot and socket joints along the web, and in some cases along the flange as well; the flanges being machined and jointed by a machined steel fishplate, as illustrated in Fig. 127. The guide is fastened to steel plates at intervals of about 6 ft. by malleable iron clamps, a typical example of which is shown in Fig. 125. The back plates are secured to the well by through bolts or Lewis bolts, spacing pieces being interposed between the plates and the well. Alternatively, the back plates, either flat or angle iron, may be bolted to the steel well structure.

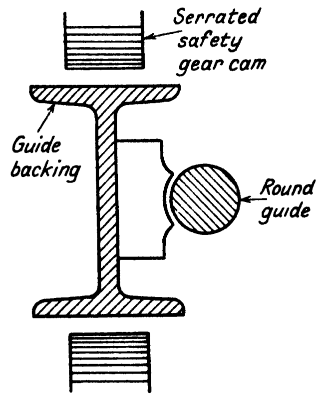


FIG. 123
OPERATION OF SAFETY GEAR ON GUIDE BACKING

Fig. 126 shows methods of fixing car and counterweight guides when landing openings on opposite sides are required, and it becomes necessary to fix a car guide on the same wall as the counterweight guides. In (*a*) the counterweight guides are fixed to channel irons by the usual clamps, these channels being fixed to the well every 6 ft. Similar spacing is adopted for the car guide fixings, the guides being secured to iron straps which brace the two channel irons. In (*b*) a similar result is obtained by using iron straps instead of angles.

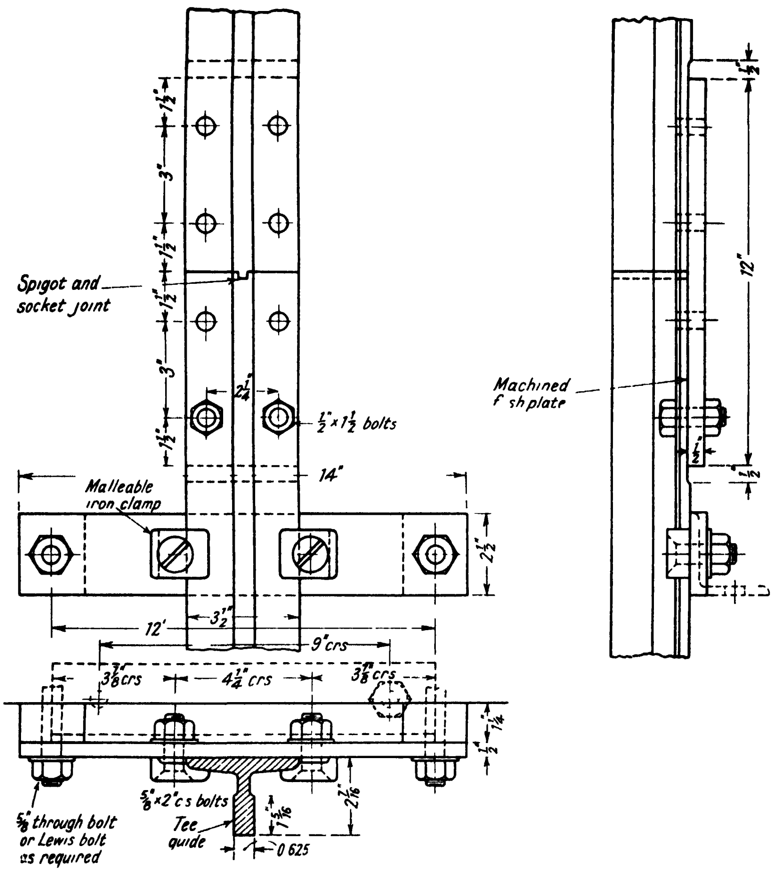



**Fig. 124. Arrangement of Car Guide Fixed to Wall or Steel Structure**

Showing method of jointing

(*R. J. Shaw & Co*)

Other methods of fixing counterweight guides and counterweight guards are shown in Fig. 128. In (*a*) the guides are secured to the well by angle irons, and in (*b*) by short lengths of angle, either embedded in the well or bolted to the steel structure. A bracket for attaching the counterweight guard to the counterweight guides is shown at (*c*).

In very high buildings the guides cannot be attached rigidly

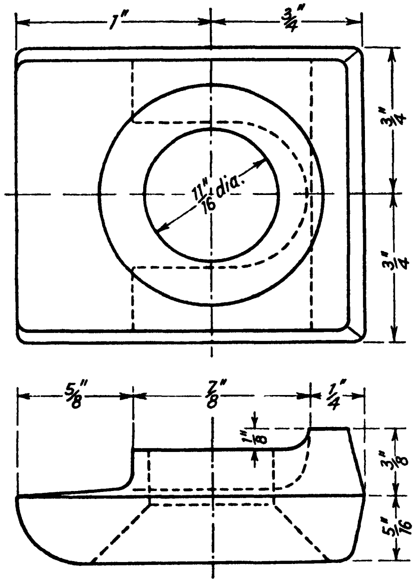



FIG. 125. MALLEABLE IRON GUIDE CLAMP FOR TEE GUIDES
(*R. J. Shaw & Co*)

to the building which is an elastic structure. In such buildings in America the guides are fixed to their brackets by clips which exert a constant spring tension on the guides. This permits the guides to slide through the clips and thus take care of building movement.

**Guide Lubrication.** The guides are exposed to dust and dirt from the well and landings, and to keep them lubricated satisfactorily is not an easy matter. It is important that they should be adequately lubricated to minimize wear of guides and shoes and to ensure comfortable riding conditions. With

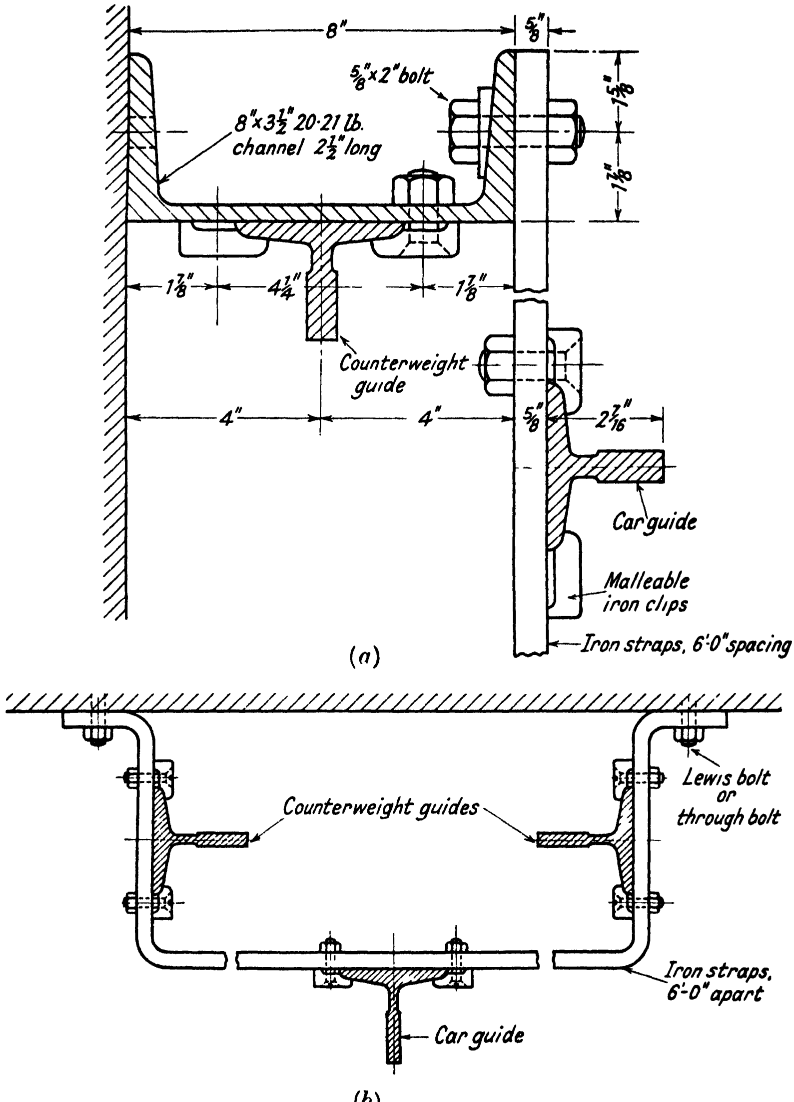



**Fig. 126. Methods of Fixing Car and Counterweight Guides**

(a) Car guide fixed to counterweight guide brackets
(b) Car guide fixed to counterweight guide straps

FIG 127 TEE GUIDE, SHOWING METHOD OF JOINTING AND TYPICAL SHOE
(*Express Lift Co Ltd*)

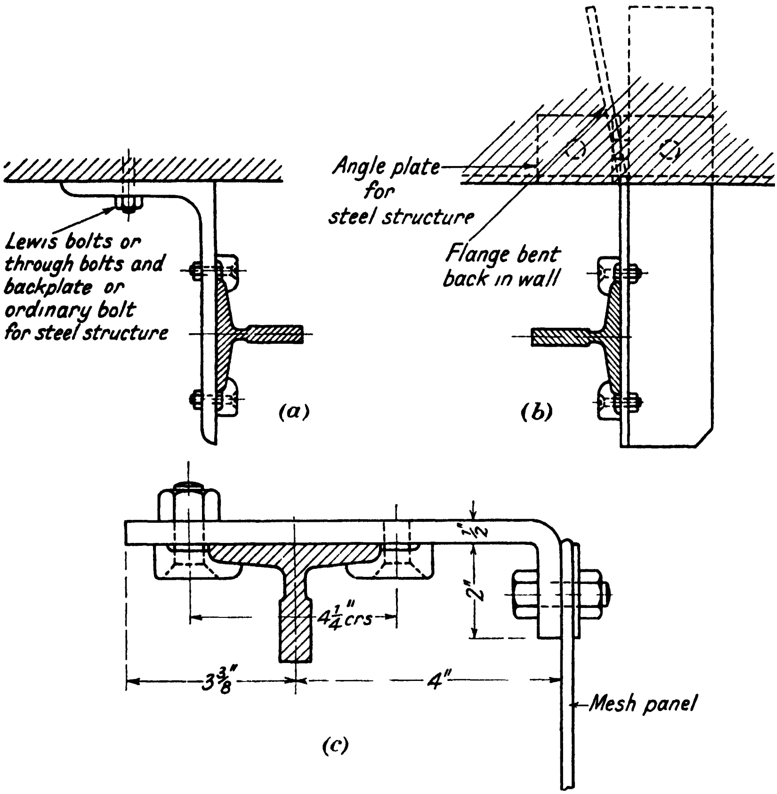



FIG 128 COUNTERWEIGHT GUIDES AND GUARDS

(a) and (b) Other methods of fixing counterweight tee guides
(c) Bracket to fix wire mesh guards to counterweight guides
(R J Shaw & Co)

many of the older slow speed lifts the guides are painted with heavy oil or grease at regular intervals, but most lifts of recent construction have their guides lubricated by automatic means and this is standard practice to-day. A number of different types of automatic lubricators are in use, some employing oil and others grease. Thin oils tend to run down the guides and

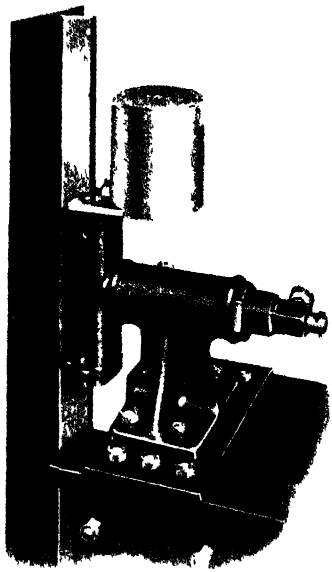


FIG. 129. GUIDE LUBRICATOR
(*Waygood-Otis, Ltd*)

wash off the dirt but if the contract speed is high the oil may be thrown off the guides by the shoes and might find its way to the inside of the car. The design of an oil lubricator must therefore incorporate some means which will ensure that too much oil is not used. Although grease adheres to the guides better than oil it has the disadvantage of holding dust and dirt.

Some guide lubricators are of the stationary type consisting of an oil reservoir mounted at the top of each guide, the oil being fed to the guide by wick feeds. It then runs down the

guide to the bearing surfaces. The most popular lubricators, however, are of the travelling kind and these consist of two lubricators mounted on the car for lubricating the car guides and two on the counterweight for lubricating the counterweight guides. A lubricator fitted to a shoe is shown in Fig. 106. Another type for attachment to the car and counterweight guide shoes and which uses heavy oil is shown in Fig. 129. This latter lubricator holds about 1½ quarts of oil, the rate of flow of which may be regulated by a screw adjustment.

A recent development is the use of dry guides with which carbon lined shoes are employed. Messrs. Morgan Crucible Co. have experimented with this type of shoe on some recent lifts and the results are promising. The lining is composed of three flat carbon plates held against the three sides of the shoe by metal keep plates screwed to the top and bottom of the shoe. The linings are backed by thin sheets of rubber bonded to the carbon plates. This minimizes the effect of shock on the carbons and also retains them in position if they crack. The main advantage of this type of shoe is that lubrication is not required and thus the guides and the outside of the car can be kept clean and maintenance reduced.

# CHAPTER X

## GATES, DOORS, AND LOCKS

**Gates.** Until recent years the most common form of protection for lift car and landing entrances was the collapsible steel gate of the overhung type. The gate is supported by ball-bearing rollers running on an overhead track, the pickets being guided by a self-cleaning channel-shaped bottom track. The gates are of the close picket type in which the openings between pickets do not exceed $2\frac{1}{2}$ in. in width when the gate is fully extended. When used on landings the leading picket is widened to accommodate the electro-mechanical lock. Where a particularly silent gate is required, as in hospitals, rubber buffers are fitted between the pickets. A hollow tube gate construction, which eliminates the shearing hazard, is sometimes adopted, the tubes frequently being arranged to run around the side of the car when open, thus giving an opening equal to the full car width. Gates can be made of bronze, aluminium alloy or stainless steel and may be chromium-plated if required. Sometimes they are finished in cellulose, copper- or brass-plated, or bronzed. Most gates are of the single side opening type, although for large cars double centre-opening gates are sometimes provided. To ensure sufficient rigidity the gate should withstand a pressure of 75 lb. applied at points on two adjacent pickets so as to divide the load equally. A typical midbar gate is shown in Fig. 130. Gates have now largely been superseded by doors, particularly as protection for landings, and on the higher-grade passenger lifts.

**Doors.** The advantages of doors over gates are that they are quieter, they eliminate draughts emanating from the well, prevent noise being transmitted to various floors via the well openings and also improve the appearance of a lift. The rigidity of doors enables them to be operated by power in a more satisfactory manner than gates. To prevent the possibility of a person being trapped between the landing and car doors, the distance between the well side of the landing door and the lift-well edge of the landing threshold should not exceed 4 in. for hinged doors or $2\frac{3}{4}$ in. for sliding doors or gates.

HINGED DOORS. These are used on landings and may be of the single pattern or of the double centre-opening type and can give a clear opening equal to the full car width. These doors,

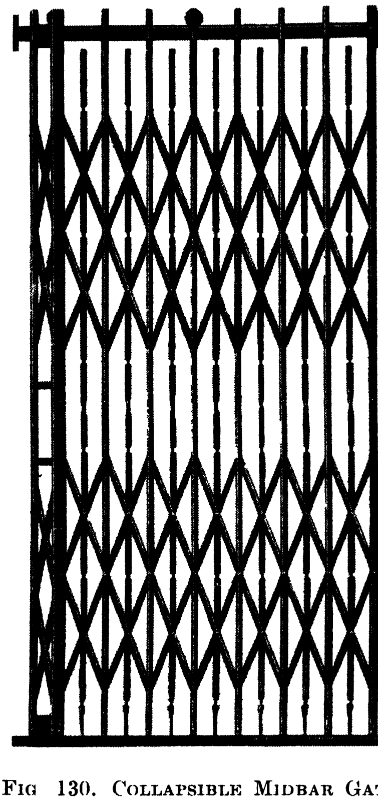


FIG 130. COLLAPSIBLE MIDBAR GATE
(*Express Lift Co Ltd*)

however, require lobby space in which to swing and are now seldom used, having been replaced by sliding doors.

SINGLE-PANEL SLIDING DOOR. A typical door of this type is shown in Fig. 131. The vision panel should be of safety or wired glass. This entrance is used where moderate openings of about 3 ft. are required, this usually being a little more than half the car width.

TWO-PANEL SLIDE. One panel slides behind the other, the former at twice the speed of the latter, and both panels therefore arrive at the fully-opened position simultaneously. The clear

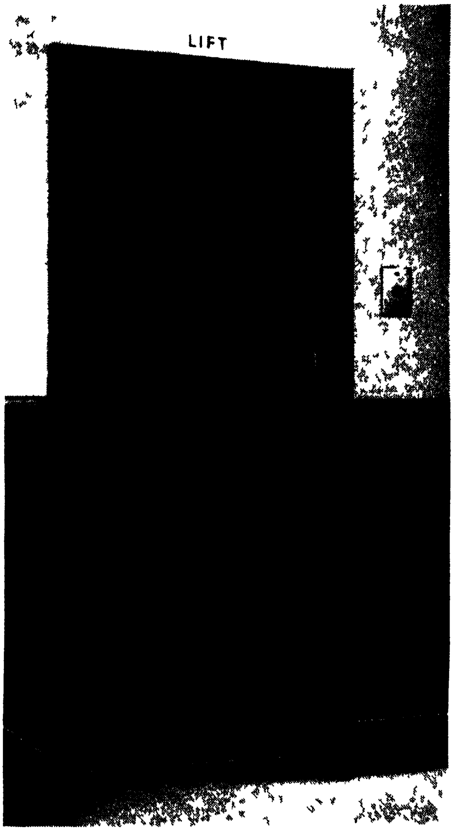



FIG 131 SINGLE LEAF (FLUSH) SLIDING DOOR
(*Marryat & Scott*)

opening is about two-thirds of the car width. A greater depth of sill is required with this type than with a single-panel or two-panel centre-opening sliding door. A two-panel sliding door is shown in Fig. 132.

TWO-PANEL CENTRE-OPENING SLIDE. One-panel slides to

the left and the other to the right. Rubber bumpers are fitted on the edges of each leaf to minimize the shock when closing. The clear opening is about half the car width. An important advantage of these doors is that the operating time is half that of other types as the distance to be moved is only half the opening width. Since these doors have two mechanical con-

FIG. 132. TWO-PANEL SLIDING DOOR
(*Marryat & Scott*)

nexions to the operator, there are two self-cancelling reactions, no twisting action is imparted to the car, and high door speeds can be used. For these reasons this type of door is very popular for the wider passenger cars and also where high car speeds are employed and it is desirable to take full advantage of such speeds by cutting down the door operating time to a minimum. A door of this type is shown in Fig. 133.

TWO-PANEL, SLIDING AND STATIONARY. The sliding panel moves behind the stationary panel and the opening is therefore equal to the width of the sliding panel which is about half the car width.

THREE-PANEL TWO-SPEED, SLIDING AND STATIONARY. The two sliding panels move behind the stationary panel, one at

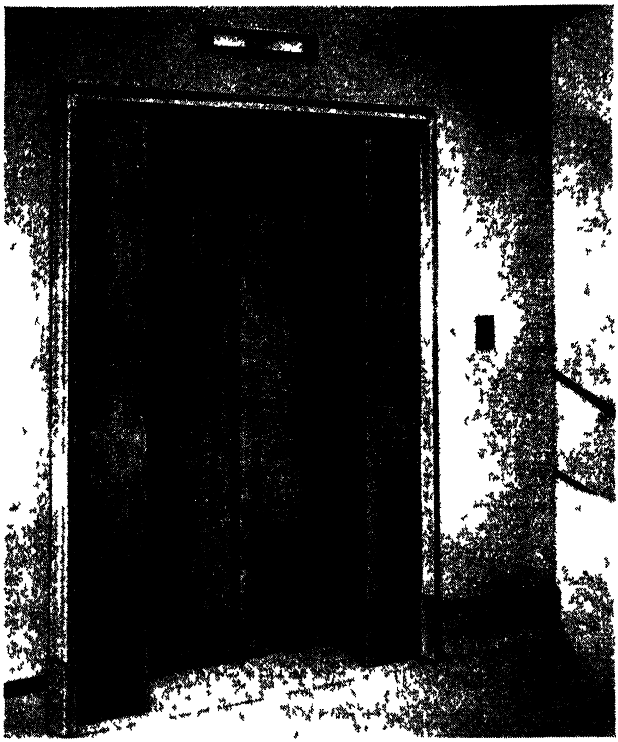


FIG. 133 CENTRE OPENING DOOR
*(Wm Wadsworth & Sons)*

twice the speed of the other so that both panels arrive at the fully open position simultaneously. This gives the entrance a characteristic pleasing stepped appearance. The door is sometimes used where it is desirable to produce architectural symmetry in the corridor treatment for landing entrances which would be off-centre or improperly located with any other type

of entrance. The opening is approximately two-thirds of the car width. Fig. 134 illustrates this entrance.

FOUR-PANEL SLIDING, TWO-SPEED CENTRE-OPENING. Two panels slide to the left, one at twice the speed of the other, the

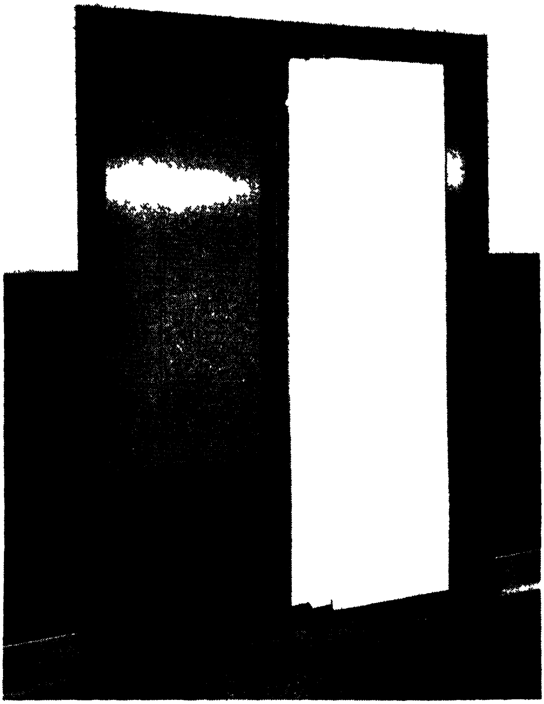


FIG. 134. THREE PANEL, TWO SPEED DOORS
(*Wm Wadsworth & Sons*)

remaining two leaves slide similarly to the right. This is sometimes used on large passenger cars.

MULTI-PANEL SLIDING. This consists of any number, between about three and twelve, of narrow panels. The panels telescope behind one another as the door opens and give an opening of about half of the fully-extended width for the small sizes and three-quarters for the larger sizes. The door, which is

attractive in appearance, is sometimes used on wide passenger cars and is shown in Fig. 135.

COLLAPSIBLE STEEL-SHUTTER DOOR. This is a sliding door comprised of a large number of narrow panels which collapse

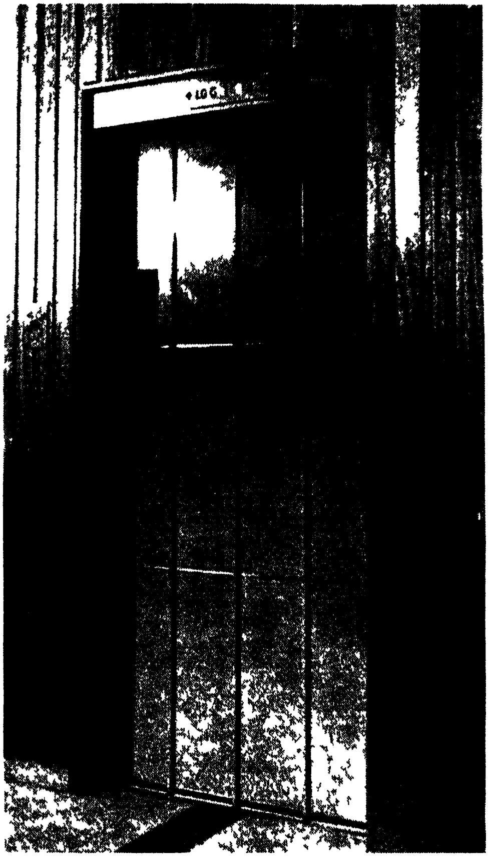


FIG 135 PASSENGER LIFT WITH MULTILEAF DOOR
(*Marryat & Scott*)

into a small space. It is very popular for the entrance of goods lifts because it gives a particularly wide opening. They exclude draughts and are fire-resisting. As an alternative to steel, they are available in aluminium alloy. The individual

panels may be 4 in., 6 in., or 9 in. wide. An inspection window of shatter-proof glass is usually fitted to the leading panel. This door is illustrated in Fig. 136

VERTICAL BI-PARTING DOOR This consists of two panels

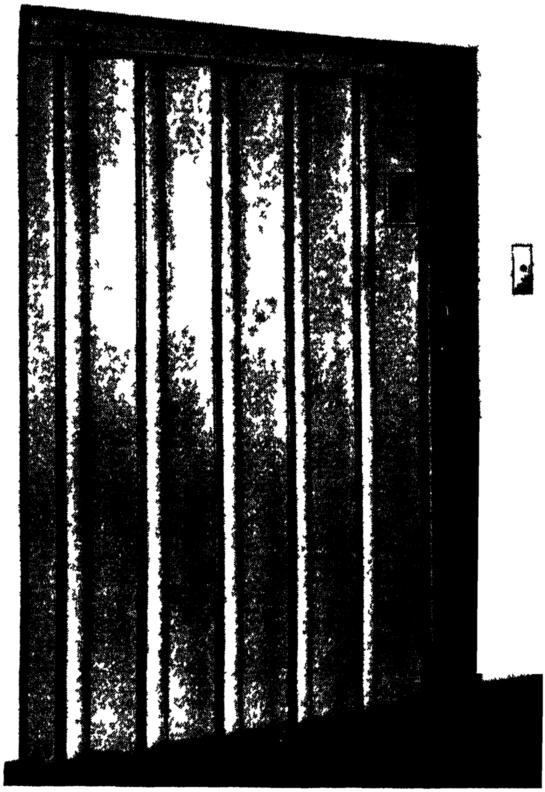


FIG. 136 COLLAPSIBLE STEEL SHUTTER DOOR
(*Marryat & Scott*)

which slide vertically, one upwards and the other downwards. The panels are connected so that they move simultaneously These doors are robust and strongly constructed and will stand more rough treatment than any other form of door or gate, consequently they are usually fitted on large goods lifts and,

because of their weight, are generally power-operated. The doors, however, are counter-balanced so that they can be moved with the minimum effort. They are expensive, but as they

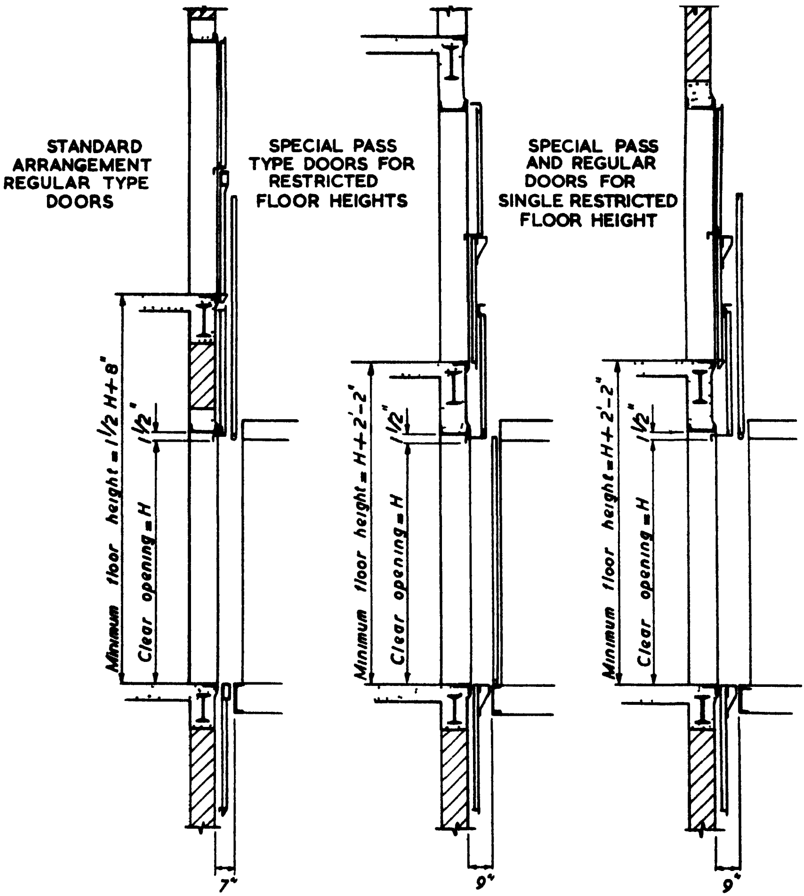



FIG. 137. BI-PARTING DOORS
(*Express Lift Co Ltd*)

cannot be damaged by trucks during loading and unloading, their maintenance costs are small. The rising car gate used with these power-operated doors is generally formed of wire-mesh panels in a steel section frame. Another advantage is

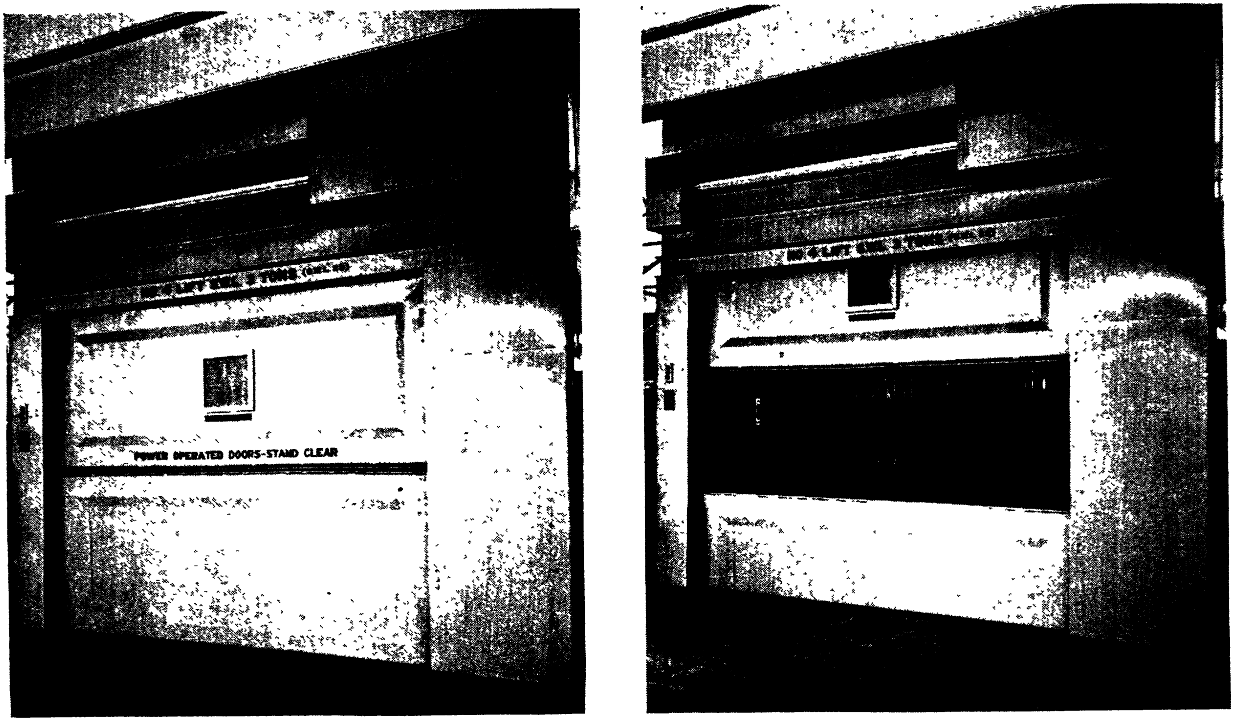



FIG. 138. POWER-OPERATED BI-PARTING DOORS
(*Marryat & Scott*

that they provide a full car-width entrance. The standard type of bi-parting door requires a minimum floor to floor height of about 12 ft., but for restricted floor heights, a special pass type, in which the rising top portion of one door passes the lower panel of the door above, is available.

The risk of injury between the two panels is lessened by providing cushioned edges and having a slipping clutch in the door-operating mechanism. To prevent trapping between the one-piece car door and the bi-parting landing door, the car door can close before and open after the landing door. Fig. 137 shows the space required for the various arrangements of bi-parting doors in which both the landing doors and the car gate are power-operated by the same operator. Fig. 138 is of an entrance with power-operated bi-parting landing doors and manually-operated collapsible car gate, whilst Fig. 139 shows manually-operated bi-parting steel doors for the landing and car entrances.

Sliding doors are invariably overhung, the bottom edges being provided with rectangular guides that travel in the machined grooves of the sills. Rubber bumpers are fitted on the top and bottom door stops to minimize shocks when opening and closing. Doors may be constructed of wood and finished to harmonize with the surrounding landing architecture. Probably the best practice, however, is to use sheet steel No. 14 or No. 16 gauge, suitably framed and filled and reinforced if necessary to receive the operating mechanism. The advantages of sheet steel doors are that there is no tendency to lose shape, as is the case with wooden doors, and the fire risk is lessened. Door hangers consist of ball bearing hardened steel rollers mounted on steel brackets fixed on the top of each panel. The rollers are about 3 in. in diameter, two being provided for each panel. Specially shaped top steel tracks on which the door rollers run are fixed to the door frame. A small ball bearing check roller is mounted immediately below each main roller and on the same bracket and engages the under side of the track. These check rollers prevent the doors from being lifted upwards. A large number of door designs is available, but every landing door should be provided with a "fire-resisting" vision panel. The decorative designs may be applied by stippling, stencilling, or a transfer process. Plain colours, grained, or bronze enamel

finishes are very popular, whilst further decoration is sometimes obtained by means of strips of bronze, monel metal or non-oxide steel applied to the doors.

**Methods of Operation.** Collapsible gates or solid doors may be operated by one of the several methods detailed below.

MANUALLY OPERATED. The landing and car doors are opened and closed by hand after the car has arrived level with the landing and released the locks.

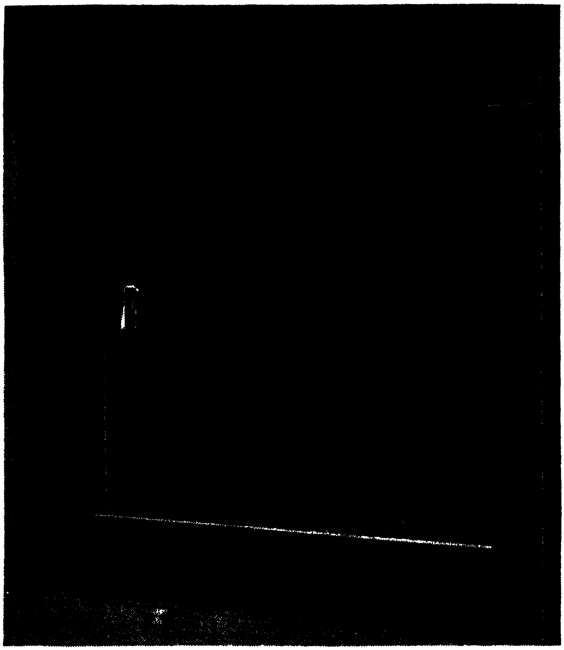


FIG. 139. VERTICAL BI-PARTING DOORS
*(Wm. Wadsworth & Sons)*

One method of reducing the labour involved in opening and closing the car and landing gates makes use of an electro-magnet fitted to the car gate. This magnet, when energized, magnetically connects the landing and car gates together through the medium of a hinged iron plate fitted on the inside of the landing gate. Thus both gates are opened in one movement instead of two.

SELF-CLOSING. In this form, the door or gate is opened manually but closes automatically when released. The closing is usually effected by means of springs, the action of which is cushioned by a dashpot, or alternatively by a falling weight connected to the door by a light chain. Sometimes light single doors are linked together when the lift stops at a landing so that movement of one door operates the two, and by giving a mechanical closing bias to the doors they automatically close when released.

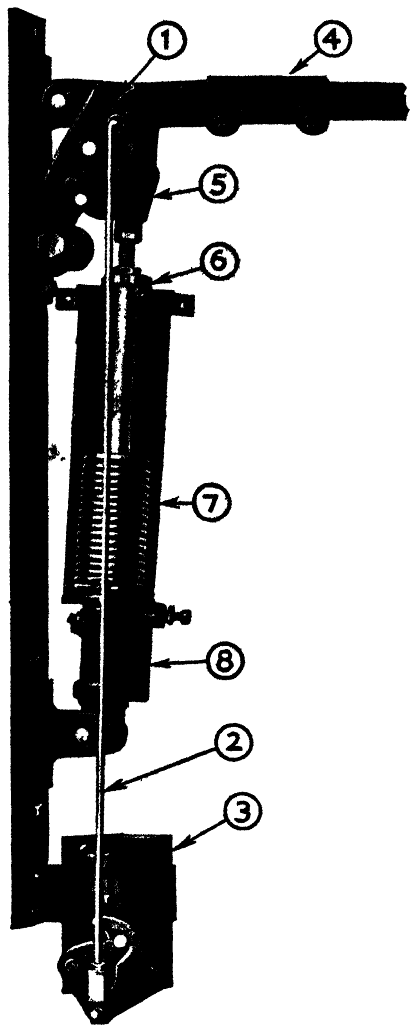


FIG. 140. DETAILS OF CLOSER
(*Waygood-Otis, Ltd*)

Fig. 140 shows details of a closer in which (1) is the mechanical locking device which prevents the re-opening of the door when closed to within 2½ in. of the door jamb. The connecting rod (2) operates the electric interlock (3), this occurring when the door is within 2½ in. of the door jamb, at which point the door is mechanically locked and the interlock contact closed. The adjustable closer arm is at (4) and the connecting piston yoke at (5). Adjustment for the tension spring (7) is provided at (6),

whilst the oil dashpot (8) cushions the door without noise or shock.

Power Operation. In this form the door is both opened and closed by power, other than by hand, gravity, springs or the movement of the car. The power employed is either an electric motor or compressed air, the latter acting on a plunger in a cylinder, the plunger being connected to the door through a system of levers. If a failure of the electricity supply or air pressure occurs, the operating mechanism is so arranged that it may be readily disconnected and the doors operated by hand. High door-operating speeds are employed only if means are adopted to prevent passengers from being struck by doors. In one method of achieving this photo-electric cells are used. The exciting lamp is fitted on one side of the entrance and illuminates a photo-electric cell fitted on the other side. When a person passes and interrupts the beam of light, the cell operates a control relay and prevents the closing of the door. There is now a tendency to use higher speeds for opening than for closing.

In one form of power operator, Open and Close buttons are fitted in the car and at each landing. Momentary pressure of a button will cause the doors to open or close. In this case arrangements must be made to ensure that the landing buttons are only operative when the car is level with that particular landing.

A typical example of the Express Lift Co.'s door operator is shown in Fig. 141. The motive power is a small squirrel cage motor coupled by a vee-rope drive to a worm reduction gear. This turns an operating lever through a half-revolution, the power being transmitted through an adjustable friction clutch. The operating lever is connected to the doors so that this half revolution causes the doors to complete an opening or closing movement. The motion approximates to simple harmonic, and thus no additional means, mechanical or electrical, are required for accelerating or retarding the motion of the doors. The operating lever assumes a dead-centre position with respect to the connecting rods, both when the doors are fully opened and fully closed. This is necessary to obtain the harmonic motion, but it also constitutes a lock on the doors. On centre-opening doors the levers are attached directly to the door

hangers without the interposition of connecting links, thus involving a minimum of levers and bearings. The mechanical connexion between the car and landing doors consists of a retractable driving vane on the car door which engages with a

FIG 141 POWER DOOR OPERATOR
*(Express Lift Co Ltd)*

fixed driving block on the landing door, this vane being withdrawn by a solenoid before the car can move away. The vane also operates the landing-door prelocks.

To enable passengers to open the car and landing doors if the car stops near the landing and the doors do not open, a spring-loaded ball catch is incorporated in the connecting rods between the operating lever and the door. When the doors are closed, it

is possible to release the ball catch and telescope the connecting rods by pulling the doors open. The spring load on the ball catch is adjustable and is set so as to transmit a reasonable margin of power above that necessary to operate the doors. In the event of power failure resulting in the de-energizing of the

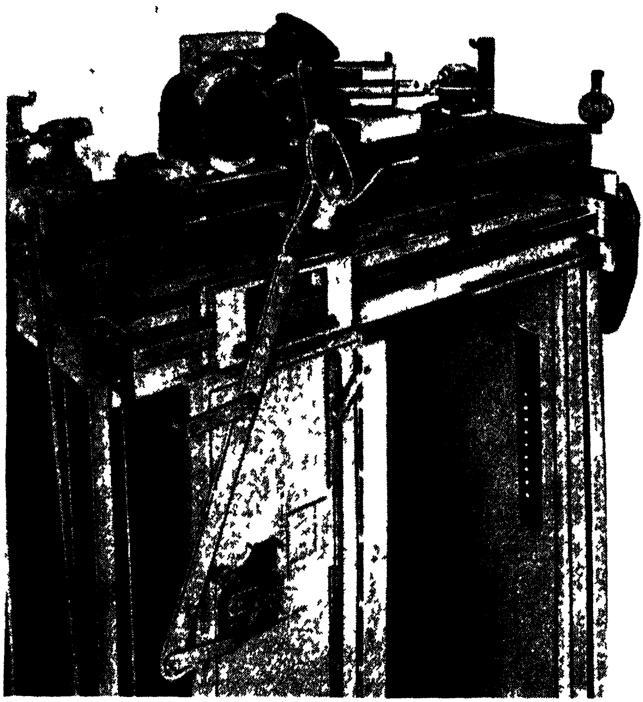


FIG. 142 CAR DOOR OPERATOR
(*Etchells, Congdon & Muir*)

magnet, the retractable vane is ejected under spring pressure so that the landing door opposite the car would be engaged by the vane and unlocked and so be free to move with the car door.

The mechanism will not cause injury to a passenger caught by the closing doors as these are driven through a friction clutch which transmits only sufficient torque to operate the doors, and the drive would slip if the doors met an obstruction.

Another power door operator is shown in Fig. 142. This is

mounted on the car and consists of an electrically driven worm reduction gear driving the main arm through a friction clutch, crank and connecting rod. The main arm is connected to the car door to which it imparts harmonic motion. The car door is equipped with a coupling mechanism with retractable rollers which engage with adjustable driving plates on the landing

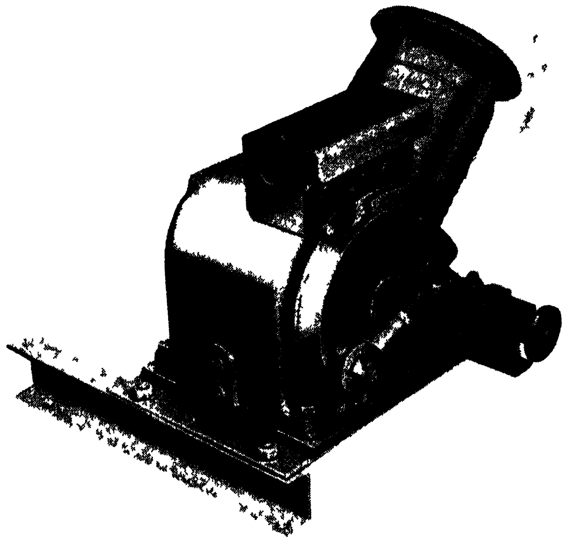


Fig. 143 Car Door Operator Power Unit
(Etchells Congdon & Muir)

doors so that both doors operate simultaneously. When the car moves away from the landing, the rollers on the coupling mechanism retract and are thus free of all door driving plates until the lift stops. When the doors commence to open, the coupling mechanism automatically grips the driving plate on the landing doors so that the subsequent opening and closing of the doors is carried out without any lost motion. The main driving arm is provided with a release mechanism which enables the doors to be opened by hand from either the car or the landing. This mechanism automatically resets itself when power is applied to the door operator. A sensitive edge is fixed to the edge of the car door so that the action is reversed if the

door meets an obstruction. Figs. 143 and 144 show details of the power units, the former being suitable for openings of 3 ft. to 4 ft. and the latter, with a chain drive to the main arm, for openings between 4 ft. and 5 ft.

**Car Gate or Door Locks.** Every lift car gate or door is fitted with an electric interlock which prevents the movement of the car by cutting off the supply to the control circuit, unless the

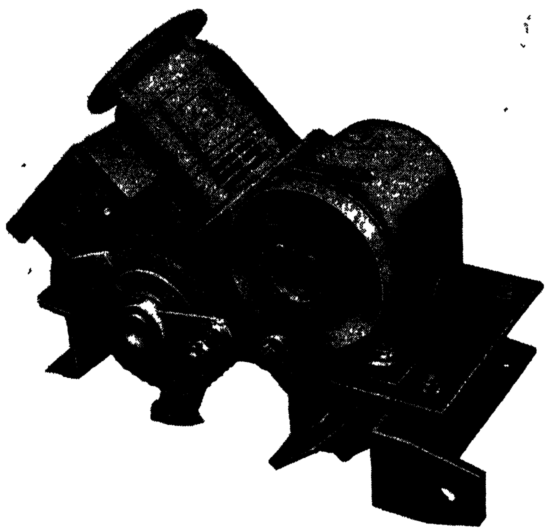


FIG. 144 CAR DOOR OPERATOR POWER UNIT
(*Etchells, Congdon & Muir*)

gate or door is properly closed. It is permissible however, for the car or landing gate or door to be open when the lift is levelling at slow speed within 15 in. above or below landing level. A car gate interlock is shown in Fig. 145. This lock is fitted to the top gate track in such a position that the leading picket raises the lock contact arm and short-circuits the two contacts when the gate is in the closed position. Immediately the gate commences to open, the arm drops due to the combined effects of gravity and a spring, and the control feed is cut off. Another contact suitable for a car gate or car door is shown in Fig. 146. The roller striker fixed to the door presses

home the rocking lever when the door is closed and thus completes the interlocking circuit. Opening the door breaks the circuit positively as the striker bears on the tail of the rocking lever.

Cars having an entrance which opens into a space in any portion of the lift travel which is in excess of 5 in. should have the gate or door to that side of the car protected by a mechanical locking device with an electrical interlock.

**Car Gate Delayed Contact.** It is frequently the practice, when a lift is worked on the automatic control system, to arrange that after a passenger has entered the car and closed both car and landing gates, a period of 5 to 10 sec. is allowed during which the landing buttons are cut out of circuit During this period the car is under the sole control of the passenger in the car who is thus given time in which to select and operate the desired car button. If a car button is not pressed within the period allowed, the car may be called to any landing in response to pressure on a landing button. This facility is generally provided by incorporating an auxiliary delayed contact in the car gate lock box, this contact disconnecting the landing buttons from the control circuit for the desired period, immediately the gate is closed.

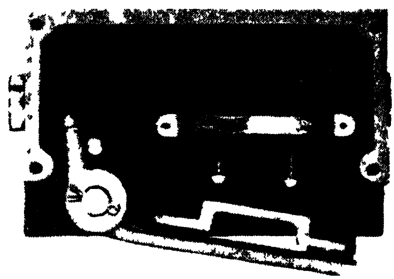


FIG. 145. CAR GATE INTERLOCK
(*Marryat & Scott*)

**Landing Gate or Door Locks.** Several different types of lock are employed for landing gates or doors, the particular lock used depending upon the method of operation of the gate or door. The main objects of all types, however, are to ensure that the gate or door cannot be opened until the car is either level with the landing or within that particular landing zone, and that the car cannot be moved unless all gates are closed. Arrangements are made for the opening of the gate or door, in

case of emergency, by means of a special key, irrespective of the position of the car.

The most common form of locking system for landing gates and doors comprises a lock box which is fitted to the gate or door framing. The lock consists of a mechanical lock combined with an electric interlock, the control circuit being completed

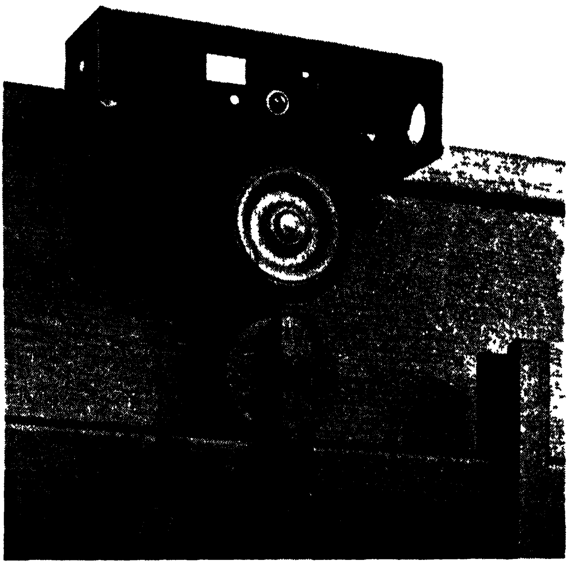


FIG. 146 CAR GATE CONTACT
(*Dewhurst & Partner, Ltd.*)

(except for pressure on a car or landing button or the operation of the car switch) when the electrical interlock is operated. The door is mechanically locked before the interlock makes contact. Hence, before the mechanical lock can be released to open the door, the electrical interlock must be broken, thus disconnecting the control circuit.

An example of a modern lock is shown in Figs. 147 and 148. This incorporates a pre-locking feature in which the lock must be proved to be mechanically locked before the lift can start. The lower contact is the electric interlock and the upper contact the counterlocking or prelocking contact. When the beak is

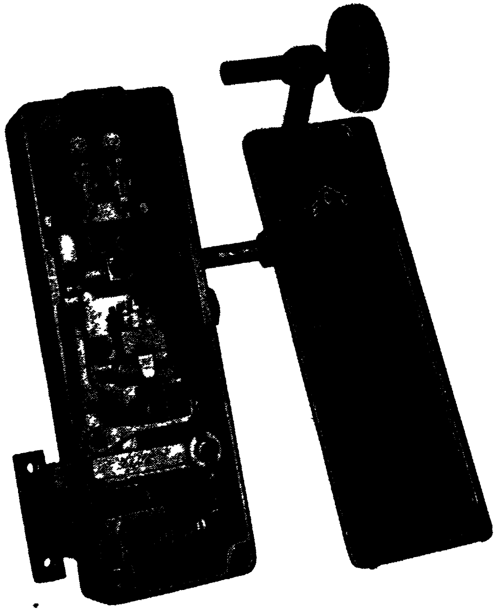


FIG 147 LANDING DOOR LOCK (CLOSED)
(*Etchells Congdon & Muir*)

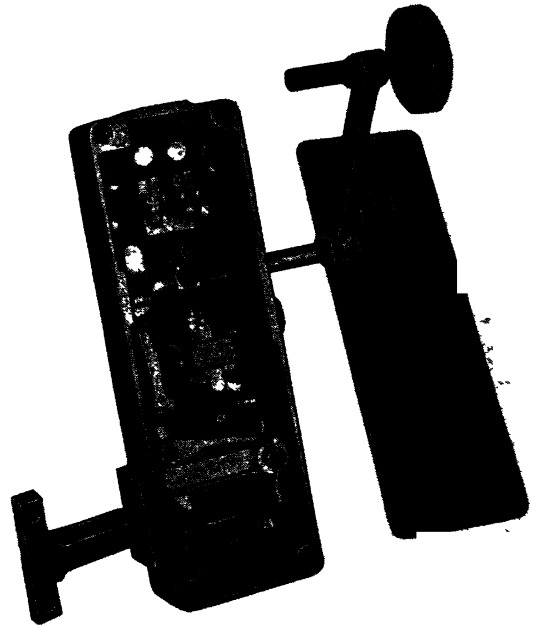


FIG 148 LANDING DOOR LOCK (OPEN)
(*Etchells, Congdon & Muir*)

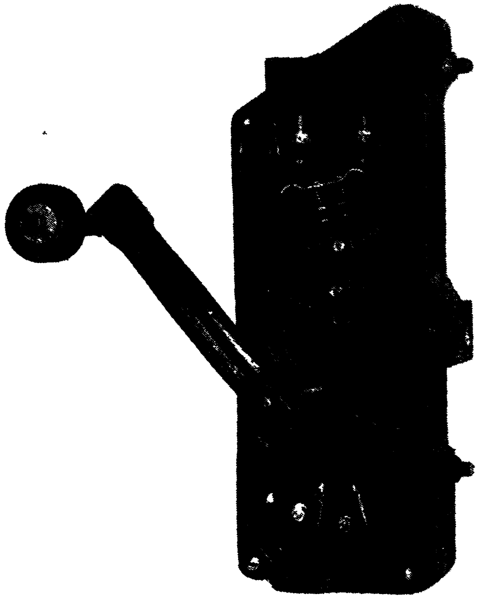


Fig. 149. Landing Door Lock
(*Wm. Wadsworth & Sons*)

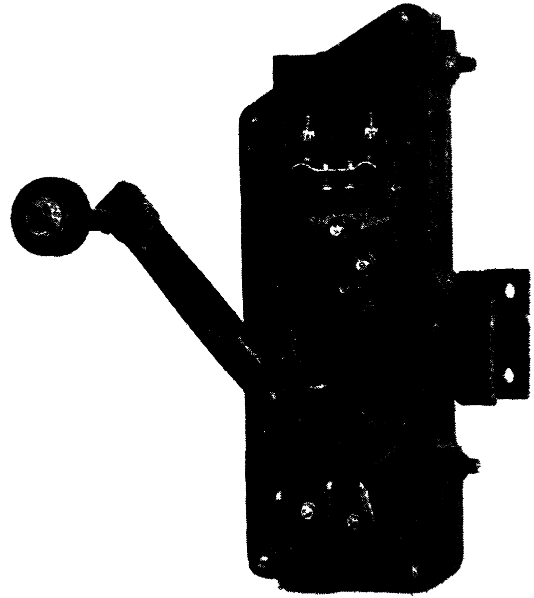


Fig. 150. Landing Door Lock
(*Wm. Wadsworth & Sons*)

moved into the lock to close the door the lower contact makes after the beak is in the locked position and ready to be counterlocked. This lower contact closes certain preparatory circuits, including the retiring cam coil. The cam on the car can now be electrically retired by the operation of the push button or car switch. This causes the roller arm spindle to rotate under the action of a spring and so lowers the counterlocking plate which first performs the mechanical locking and a little later closes the counterlocking contact. This contact completes the circuit for the up or down contactor coil and so starts the lift. As the lift cannot start until this contact has been made this proves that locking has actually been performed. The lock beak is counterlocked in the latched position until the counterlock plate is withdrawn by the release of the cam on the car when the lift comes to floor level. As it nears the stopping floor the cam on the car is spring-ejected, and this turns the roller arm, so raising the counterlock plate and breaking the upper switch and thus preventing the lift being restarted. The door handle is now free to unlatch the lock and open the lower contact. When the beak is withdrawn it is impossible for the counterlocking action to take place, and hence the upper switch cannot be made by tampering and so start the lift. Another landing gate or door lock of the "pre-locking" type is shown in Figs. 149, 150, 151. Fig. 149 shows the lock in the unoperated position. In Fig. 150 the door beak has entered, and the first or upper contacts are made. In Fig. 151 the cam has retired, and both pairs of contacts are made.

Another locking system employed is that in which the lift is operated only from the car, and is provided with solid sliding landing doors which are equipped with a door closer and are locked with a mechanical contrivance actuated by means of levers operated from the car side only. The door is considered closed and the car may be moved away from the landings when the door is within 2½ in. of the jamb, or in the case of centre opening doors, when these are within 2½ in. of each other, provided an approved attachment is fitted which will effectively prevent the doors from being re-opened after they have reached a limit of 2½ in. and provided also that the door closer is of such a type as will eventually carry the door to, and lock it in the closed position.

When an automatic type of control is employed and the landing doors are of the solid sliding type, equipped with a door closer, the doors may be locked mechanically by means of levers.

For service lifts, the mechanical locking unit may be separate from the electrical interlock.

**Lock Requirements.** All parts of the lock should be of

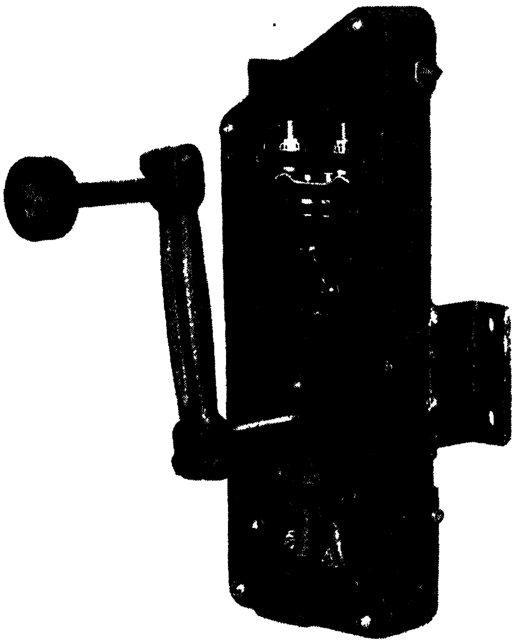


FIG. 151. LANDING DOOR LOCK
(*Wm. Wadsworth & Sons*)

substantial design and construction, and the locks must be so arranged that the electrical interlock is not made until the gate or door is closed. The contacts of the interlock should be of the solid type, and the insulation should be capable of withstanding for 1 min. a pressure of 2 000 volts a.c. The levers operating the mechanical part of the lock should be protected from interference from the landing side of the enclosure. Any spring used in the lock construction should

preferably be in compression and the contacts should be opened positively by a lever or other device operated by the door or gate. When the emergency release push is in temporary use, or when the car is being moved under the control of the levelling gear, the lock should not prevent the operation of the lift. A lock key must be provided to enable the lock at any landing to be released to provide an emergency entrance to the well. When the door is open it should be impossible to close the contact by a screwdriver, pencil or anything other than the shaped beak. As the lock is fixed in the well, maintenance is facilitated if the cover is held in position by captive screws or nuts.

In addition to the above, provision should be made on lifts operated from the car and landings to prevent the opening of any landing gate or door when the car is passing that zone in response to a call from another landing. The gate lock is operated by a cam fixed to the car, the cam hitting the gate lock arm when the car reaches a landing. On a large number of old lifts the cam strikes the gate lock arm as each landing is reached, irrespective of whether a stop is required. With a lock of this type, it will be appreciated that it is possible for a person at a landing to snatch open the door or gate as the car passes. This bad practice, apart from the possibility of temporarily putting the lift out of service, is liable to cause damage, since the gate contacts are not designed to break current. The above requirement is therefore highly desirable and on most modern lifts having a speed exceeding 120 ft. per min. and a travel of more than two floors a device known as a *retiring lock release cam* (Fig. 152) is fitted, thus making it impossible for the cam to operate the gate lock, except at the landing where a stop is to be made. The cam is withdrawn beyond reach of the gate lock arm by means of an electromagnet which is energized at all times when the car is outside the particular landing zone where a stop is required. When stopping, the electromagnet is de-energized and this releases the cam and enables it to operate the gate lock. When power operated doors are employed, the retiring cam is frequently operated by the door motor and a separate electromagnet is therefore unnecessary.

**Wiring of Locks.** The electric cables to the lock contacts should be run in conduit, which should be securely fixed to the lock box and be in electrical and mechanical continuity. The

contacts must be wired in the control circuit in such a manner that the car cannot be started or kept in motion between landing zones, unless all landing and car gates are closed and their interlocks consequently made. The landing zone is the

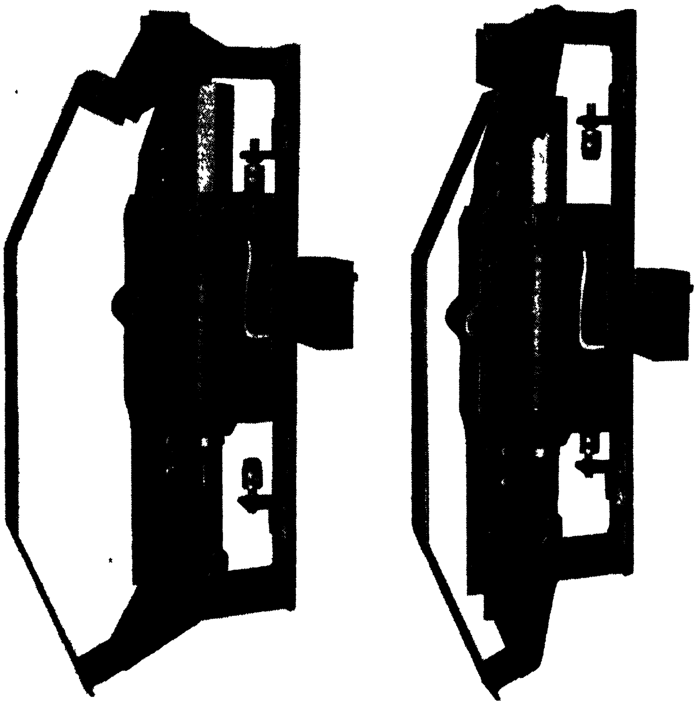


FIG. 152. RETIRING LOCK RELEASE CAM
*Left*, Normal Position; *Right*, Retracted
(*Dewhurst & Partner, Ltd.*)

space between positions not more than 15 in. above and below the landing level.

The usual method of wiring the lock contacts is to arrange for the supply to the control circuit to pass through the contacts, and this is satisfactory under normal conditions. With three-wire systems of supply, however, it is possible, if an earth fault develops, for the lift to be operated with the gates

open, which is a highly dangerous condition.* Assume that the locks are joined in the positive or line feed to the control circuit which is fed from the outers of a three-wire d.c. or a.c. supply, the centre or neutral wire being earthed. An earth fault occurring between the locks and the controller contactors will blow the + ve or line fuse but will leave half the control voltage fed to the coils, and this feed will not be controlled by the gate locks. This voltage may be sufficient to operate the contactors, but if d.c. will certainly maintain them if the lift is in operation when the fault occurs. A solution of this difficulty, and one which renders an earth fault harmless, consists in operating the control circuits from the low voltage side of the supply, i.e. between + ve or − ve, and earth or line and neutral. If the low voltage main is not available, fuses of a special type may be used in the control circuit, these fuses being constructed so that the fuse wire is connected in one side of the supply and supports a contact connected in the other side. If one fuse is in each main, the blowing of either fuse will cause the opposite side to be disconnected.

The general practice now is to use a d.c. controller, the supply for which is obtained from rectifiers when the mains are a.c. The gate locks are usually connected in one of the rectifier d.c. feeds to the control circuit. The rectifier may consist of a three-phase network, a single-phase double-wave network from outer to outer, or a single-phase double-wave network from outer to neutral, but in each of these cases an earth fault may cause the contactors to be fed by half-wave impulses not controlled by the locks. Complete safety may be obtained by joining the locks in the a.c. live main before it reaches the rectifier. Alternatively, if the rectifier is fed from the outers of the a.c. supply via a transformer, the locks may be joined in the + ve d.c. main from the rectifier and the − ve rectifier main earthed.

* "Lift Control Gear," by A. Read, *Electrical Review*, 5th April, 1935, and "Electrical Control of Dangerous Machinery," by W. Fordham Cooper, *Journal of I.E.E.*, 1947.

# CHAPTER XI

## INDICATORS

**Car Indicators.** Some form of indicator in the car is necessary with car switch controlled lifts so that the attendant shall be made aware of the floors at which persons are waiting. It is also necessary, with some forms of control, that indications be given of the directions in which the persons wish to travel. Several different forms of car indicators are available, some employing electromagnetically operated targets, and others electric lamps.

In the target indicator, the magnet targets are operated and made visible when the landing call pushes are pressed. The unit comprises one magnet-operated target for each floor served, a controlling relay, and a buzzer. On the operation of a landing call button, a magnet moves the corresponding target into view, thereby registering the signal in the car. After the call has been answered, pressure of the reset button (fitted on the car indicator unit) energizes another magnet and moves the target out of sight. Alternatively, the resetting magnet can be energized by the arrival of the car at the desired floor, in which case the target remains set until the call has definitely been answered. The buzzer gives an audible signal when the call is made and registered. Fig. 153 shows an indicator of this type.

Another form of car indicator for use in attendant operated lifts is shown in Fig. 154, and comprises a luminous bull's eye and a cancelling button for each floor. Each bull's eye glows when operated by the corresponding landing button, and the calls may be cancelled singly by the attendant as and when answered. A buzzer is provided to draw attention to the fact that calls are being made.

A typical wiring diagram for an indicator similar to that in Fig. 154 is shown in Fig. 155, the operation of the circuit being as follows. Pressure on, say, the ground floor landing push completes the circuit from +ve line through the ground floor relay, ground floor push, ground floor reset button to −ve line. The operation of the ground floor relay closes its contact and

thus provides a holding circuit for the relay via its contact, bottom contact of ground floor push and ground floor reset push, this circuit being independent of the operation of the landing push. A parallel circuit via the relay contact illuminates the ground floor indicator lamp During the operation of

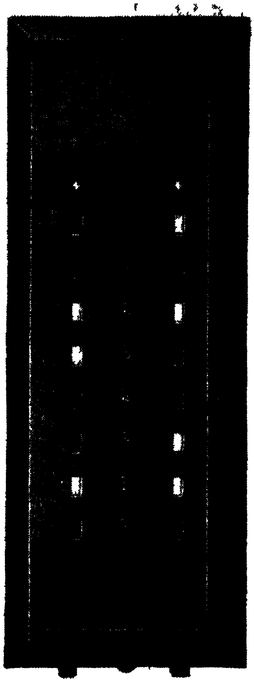


FIG 153 TARGET INDICATOR
(*Waygood-Otis, Ltd*)

FIG 154. CAR INDICATOR
(*J & E Hall, Ltd*)

the landing push, a circuit is provided for the buzzer via the ground push and reset button, this circuit being broken when the push is released. After the call has been answered, the reset button is operated and this disconnects the relay circuit, opens its contact and extinguishes the lamp.

Another type of indicator somewhat similar to that above dispenses with reset buttons, the extinguishing of the lamps being performed automatically as the calls are answered. The

relay and lamp circuits are disconnected by the opening of contacts on the landing gates, and the calls therefore remain registered until the corresponding landing gates are opened. The circuit is the same as that shown in Fig. 155, except that the reset buttons are replaced by the landing gate contacts. As in the case of the target indicator, a double row of lamps

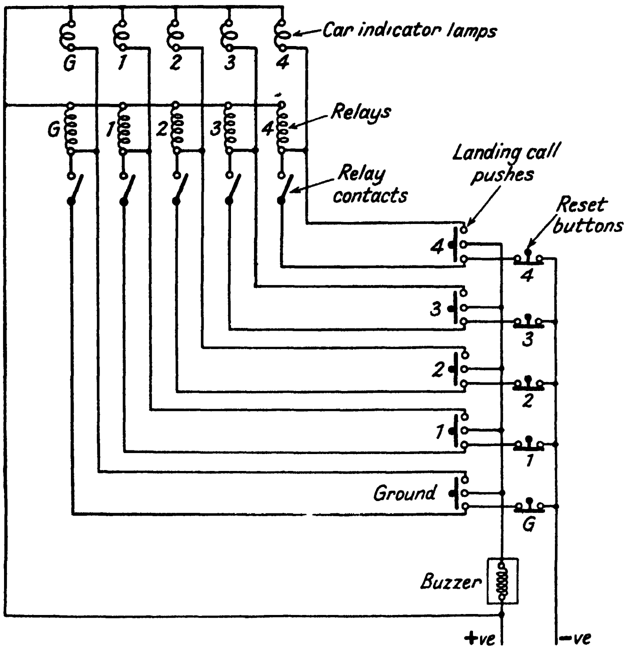



FIG. 155. CAR INDICATOR WIRING DIAGRAM

may be installed in the car when it is desired that the attendant shall know the direction in which a person wishes to travel.

An intercommunication system between each car and the landings has been developed for use when a bank of cars is operating in a building, and this ensures that only the nearest car travelling in the desired direction will answer a landing call. With this system, pressure on any up or down landing button illuminates the corresponding white up or down lamps in all cars. The attendant of the nearest car, which has sufficient room and is travelling in the desired direction, then presses

a button corresponding to the floor. The operation of this button cancels the calls in all other cars and, in addition, signals to the landing which car will answer the call and illuminates a red lamp in the car, thus telling the operator

FIG 156. CAR POSITION INDICATOR
(*Marryat & Scott*)

where to stop. The car and landing signal lamps are automatically extinguished when the landing door is opened. For a signalling system of this type each intermediate landing requires an up and down call button, whilst the top and bottom terminal landings require only a down and up button respectively. Each car requires an up and a down signal lamp at every intermediate landing with single lamps at the terminal landings. On each car indicator, every intermediate floor position is equipped with a red and a white light for each direction of travel, i.e. a total of four lights, whilst the terminal landing positions on the car indicator have a red and a white light for only one direction of travel.

A car position indicator is usually fitted in the car of modern lifts to indicate the car's position to passengers. Fig. 156 shows an illuminated indicator of this type arranged for horizontal mounting above the door exit.

FIG. 157.
DIRECTION INDICATOR
(*Express Lift Co Ltd*)

**Landing Indicators.** To avoid impatience on the part of waiting passengers it is desirable to give some indication of the car's motion at the various landings. Indicators are available which show when the car is in motion, the direction of travel, and even the actual position of the car in the well.

An illuminated bull's eye installed either adjacent to the call button or above the landing entrance, is frequently fitted

to indicate when the car is in motion and is useful, particularly when solid type landing doors are installed, and the well is, therefore, not visible to waiting passengers.

DIRECTIONAL INDICATORS. An additional feature, in which the light is arranged to glow either red or white, indicates when the car is travelling in the down or up directions respectively. Alternatively, the direction of travel may be shown by illuminated arrows or by illuminated signs, an example of the former type being shown in Fig. 157. After the lift has passed each floor, the corresponding lamp is extinguished until the lift is again approaching.

FIG. 158. POSITION INDICATOR (*Express Lift Co. Ltd.*)

POSITION INDICATORS. The tendency on most modern installations is to indicate the position of the car in the well, either with, or without, a separate direction indicator. A landing position indicator is shown in Fig. 158, the indicator being marked with embossed transparent glass letters, each illuminated singly as the car passes or stops at the various floors. A position indicator mounted horizontally and incorporating illuminated direction arrows, is sometimes mounted above the landing entrances, as shown in Fig. 159.

The wiring diagram for a landing indicator system is shown in Fig. 159A. Switches $U1$–$4$, $DG$ and $D1$–$3$ are switches of a floor selector machine installed in the main machine room. The selector machine is similar in construction and operation to the floor selector described in Chapter XIII or may be of the rotary drum pattern shown in Fig. 160. The selector shaft together with its operating arms is fixed to a pulley which is driven from the car by a steel flyrope, and each switch is arranged to close and open when the car approaches and recedes respectively from the corresponding landing. Switches $U1$–$4$ close during the upward motion of the car, whilst $DG$ and $D1$–$3$ close during the downward journey, the switches opening and closing when the car is at half the distance between floors

from the respective floors. As the car approaches the first floor in the downward direction, switch $D1$ closes and the


FIG. 159. POSITION INDICATOR
(*Express Lift Co. Ltd.*)

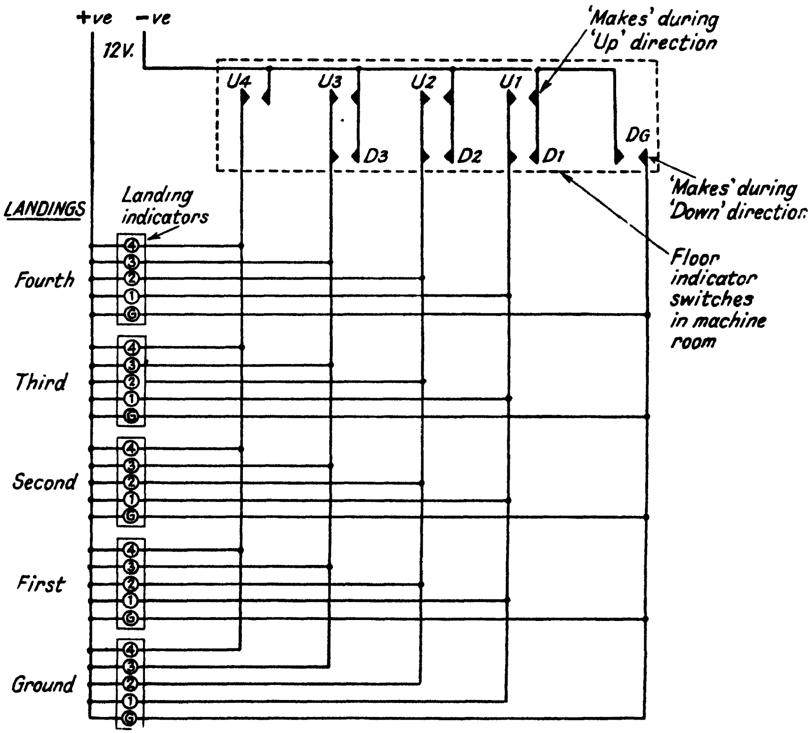



FIG. 159A. LANDING INDICATOR WIRING DIAGRAM

circuits for the first floor lamps on each landing are completed via $D1$, this switch opening after the car has left the landing. Similarly, when the car is approaching any landing, the corresponding landing lamps are illuminated, the circuits having

been completed through the *U* or *D* floor switches. If additional lamps showing the direction of travel are required on the indicators, then it is necessary to fit direction switches

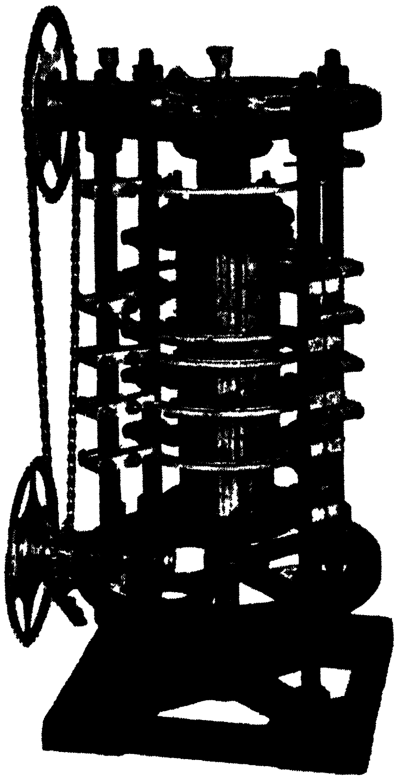


Fig. 160. Rotary Floor Indicator Switch
*(Etchells, Congdon & Muir)*

which may be operated by the main reversing contactors, one or other of these switches closing as the lift changes its direction of travel. The Up lamps are connected to one switch and the Down lamps to the other.

# CHAPTER XII

## SAFETY FEATURES

**Car and Counterweight Safety Gears.** Safety gear is invariably fitted to lift cars, with the object of preventing any uncontrolled movement of the car in a downward direction, by clamping the car to its guides should the lifting ropes break or the speed of the car, in descent, exceed a certain predetermined value. The gear is sometimes arranged to operate and clamp the car to its guides if the lifting ropes stretch unequally, as an additional safety to those mentioned above. Car safety gear is always fitted under the car framing, as cases have been recorded where the car has broken away from the safety gear when the latter has been fitted to the top of the car. Counterweights are sometimes provided with safety equipment in addition to that installed under the car, in order to stop an overspeeding ascending car and this is invariably the practice when the lift does not extend to the basement, and occupied spaces are under the well. Every lift which has a travel exceeding 35 ft. should have its safety gear operated by an overspeed governor and when any safety gear is applied, the motor and brake circuits should be opened before or at the same time. All safety gears should be applied positively and none should depend upon an electric circuit for its operation. Ropes for operating safety gears should be supported by their own pulleys and these ropes should not be less than $\frac{1}{4}$ in. in diameter. Safety gears must operate on both guides simultaneously and if a rope release carrier is used, it should be carried on the car frame and not on the enclosure. After the tripping of the governor jaws the car or counterweight should not travel more than 2 ft. 6 in. before the application of the safety gear jaws. It is essential for this time interval to be small, otherwise if the ropes break a dangerous speed may be attained before the safety gear operates. Three main types of safety gear for car and counterweights are in use, and the type adopted for any particular installation depends chiefly upon the maximum car speed employed.

**Instantaneous Type.** This gear, which is almost instantaneous in operation, is limited to speeds not exceeding 160 ft. per min.

when fitted to car frames and 250 ft. per min. on counterweights as, on account of the small stopping distance, the car and guides are subjected to heavy strains, whilst at speeds much in excess of 160 ft. per min. passengers would experience

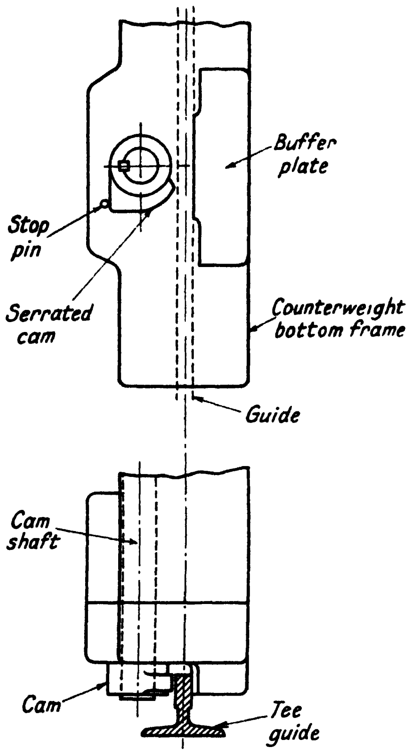



FIG. 161. INSTANTANEOUS CAM SAFETY GEAR, FITTED TO COUNTERWEIGHT

severe shock if the gear came into operation. No delayed action of the jaws is purposely introduced when this gear operates.

For light duty, the gear sometimes consists of two serrated steel cams fitted one on each side of the car and keyed to a connecting camshaft. The cams are eccentric in shape and normally travel just clear of the guides, being held away from

them by a light return spring. When the connecting shaft is slightly rotated, the leading edges of the cams are brought into contact with the guides, the remaining motion of the cams necessary to clamp the car to the guides being automatically

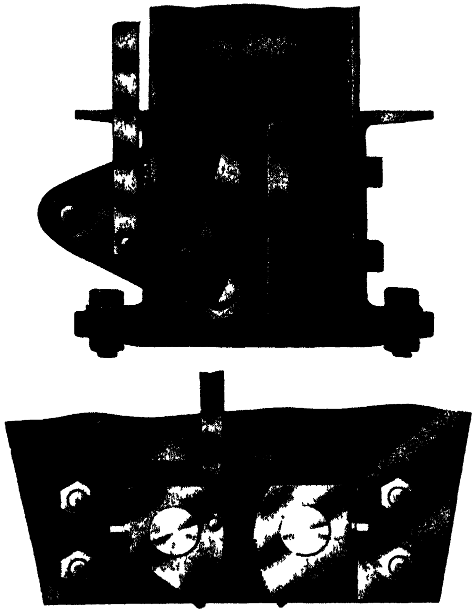


FIG. 162. INSTANTANEOUS SAFETY GEARS
(*Express Lift Co. Ltd.*)

provided by the falling car. Either the camshaft, or one of the cams, is connected to the counterweight, or to the counterweight safety gear, if fitted, by means of a flexible steel flyrope which passes over an idle pulley at the top of the well. The safety flyrope is normally slack, but if the lifting ropes break or stretch unduly, the resultant tension placed upon the safety rope causes the cams to be drawn into contact with the guides and thus clamp the car. The safety rope passes from the car safety gear over a top idler, and is then secured to one of the counterweight cams. A direct pull on the safety rope, such as would be caused by a breakage or slackening of the lifting ropes, would cause both cams to operate. Another single cam type gear

fitted on a counterweight travelling in tee-section guides is shown in Fig. 161. In this case, one cam is keyed to each end of a connecting camshaft which passes through the counterweight bottom framing. The safety rope passes from the car safety gear over a top pulley, and is then fastened to an operating arm (not shown) keyed to the centre of the counterweight camshaft. Tension on the safety rope causes a pull on the arm, which in turn rotates the shaft and brings each cam into contact with its guide, the latter being clamped between the cam and a buffer plate on the counterweight.

A better type of cam safety gear makes use of two cams on each side of the car, the cams operating on opposite sides of the same guide as in Fig. 162, or on the guide backing, and thus equal pressure is applied in opposite directions to each guide and there is no tendency for the guide to be forced out of the vertical plane. In this type, two connecting camshafts are used, each having a cam keyed at either end. The two shafts are linked together and rotate in opposite directions when the safety rope is pulled. The rope may be fastened to one of the cams, as in Fig. 162, or to one of the camshafts, but in either case it is arranged that tension on the rope will cause all four cams to operate simultaneously. The principle of operation of another system of double cams is shown in Fig. 163, although the method of operation in this case is somewhat different from those already described. The gear shown will be brought into operation if either or all of the lifting ropes break or if one of the ropes stretches unduly owing to weakness or to a faulty rope fastening. The sketch illustrates the gear fitted to the top of a counterweight, although it may equally well be employed under the car. Two lifting ropes are attached to a double lever *F* which is free to rotate about its supporting shaft *A*. The safety rope passes from the car safety gear to the counterweight, being attached to the latter at the end of the rope lever *F*. Two operating levers are keyed to each camshaft, the lever arms normally being clear of the rope equalizing lever, which, if the ropes are of equal length, should be in the horizontal position. If both lifting ropes break or stretch unduly, a tension is placed upon the safety rope which causes the equalizing lever to rotate in a clockwise direction, and push upwards the arms of the operating levers *B* and *C*, and these

in turn rotate both camshafts and cause the four cams to clamp the guides. A similar result would follow the breaking of rope $Q$ alone, whilst if rope $P$ broke the cams would be operated by the upward movement of levers $D$ and $E$. If either rope stretches unduly, the extra tension placed upon the other rope would cause the equalizing lever to rotate, and again the cams would be operated.

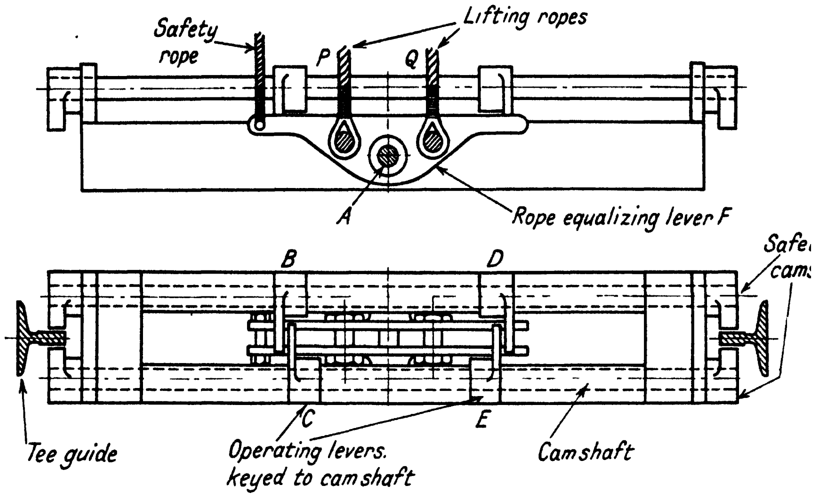



FIG. 163. INSTANTANEOUS CAM SAFETY GEAR

Another type of instantaneous safety gear sometimes used on large lifts consists of a serrated roller operating in a tapered steel block as shown in the upper illustration of Fig. 162.

The methods of operation of the cams which have been described all depend upon the lifting ropes breaking or slackening. The cams, however, may be rotated by connecting the safety rope to an overspeed governor which brings the cams into contact with the guides when a predetermined excess speed in the down direction is reached. At the same time a switch in the safety circuit is opened. By this method the operation of the cams is thus independent of any possible failure of the lifting machine. The action of the governor is described later in this chapter.

When set, the cams are released from the guides by raising the car, this being done by rotating the motor by hand with the handle usually provided for this purpose.

A repeat-action safety gear is shown in Fig. 164 in which, owing to the design of the double toggle link spring assembly, the cams once operated, are kept in contact with the guides independently of any possible failure of the safety rope. The

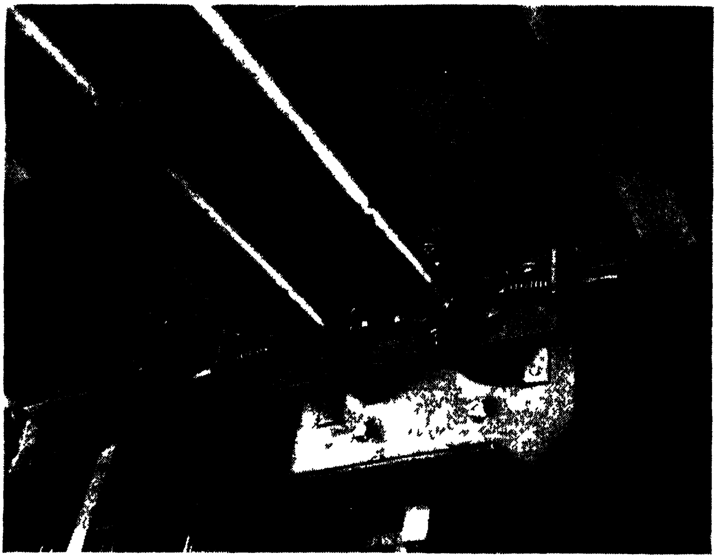


FIG 164 REPEAT-ACTION SAFETY GFAR
(*W m Wadsworth & Sons*)

safety gear will then repeatedly act to sustain the car no matter how many times it may attempt to fall. The cams cannot be rotated out of active position by raising the car until the manual resetting procedure is carried out.

**Gradual Wedge-clamp Safety Gear.** On most modern lifts running at speeds in excess of 200 ft. per min., the gradual wedge-clamp type safety gear is employed. The clamps exert a gradually increasing retarding force upon the guides, and the car is thus brought to rest smoothly, without fear of damage to the guides or shock to passengers. The gear may be operated on the broken rope principle as described above, but the more

usual method is by means of a speed governor. A view of safety gear of this type is shown in Fig. 165. The governor rope passes round the governor sheave to a special carrier fitted to the car frame, thence round a weighted pulley in the bottom of the well, and finally back to the governor sheave, as shown in Fig. 166. Instead of employing a weighted pulley to ensure a definite drive on the governor sheave, it is sometimes the practice to dispense with this pulley and insert a screw adjustment to give

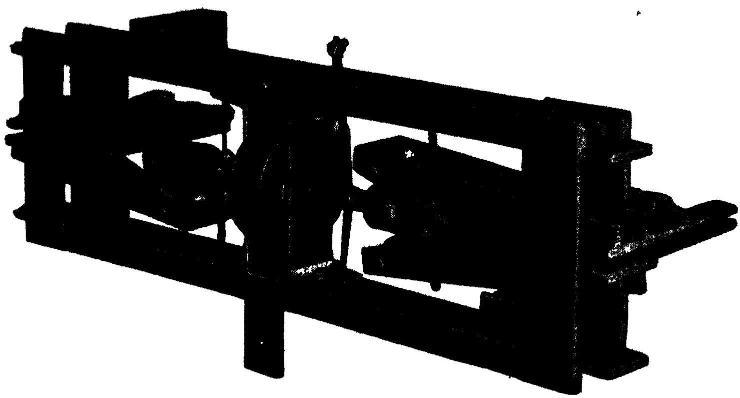


FIG. 165. GRADUAL WEDGE-CLAMP SAFETY GEAR
(*Etchells, Congdon & Muir*)

the necessary rope tension. The governor rope is, therefore, driven by the car rope carrier at a speed equal to that of the car, and the speed of rotation of the governor balls or weights, which are driven from the governor sheave, either direct or through gearing, is proportional to that of the car. The safety rope is attached to the governor rope and passes round a drum mounted under the car frame. The diameter of this safety gear drum should not be less than 5 in., and after the safety clamps have operated there should be at least three complete turns of the rope left on the drum. Under normal conditions the carrier grips the governor rope, and when the car speed reaches, say, 10 per cent above the maximum speed, the governor balls have risen sufficiently to operate a switch which cuts off power from the lift and applies the brake. If, however, the speed continues

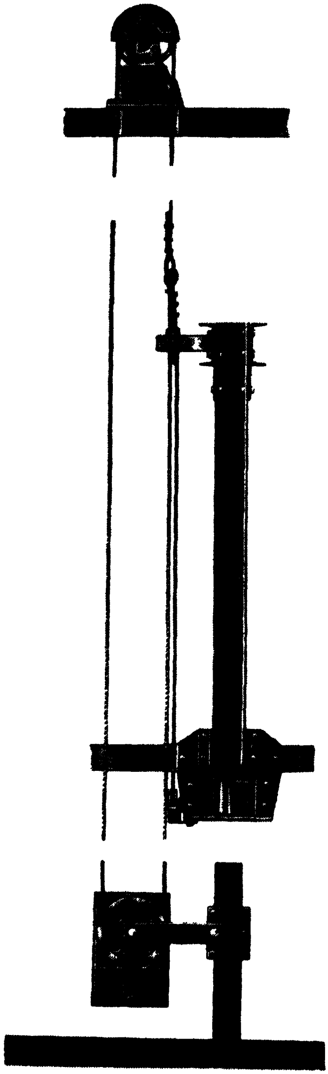


FIG. 166
GOVERNOR AND SAFETY ROPES
(*Express Lift Co. Ltd.*)

to rise to, say, 20 per cent above the maximum value, the governor balls will rise still higher, and this causes a pair of governor jaws to grip the governor rope. The rope is then jerked free of its carrier and the resulting tension on the safety rope causes the safety drum to revolve. This operates right- and left-handed screws connected to the drum and results in two powerful smooth jaws gripping each car guide and gradually bringing the car to rest.

Another type of wedge-clamp safety gear is illustrated in Fig. 167 in which the jaws are split and the clamping pressure on the guide is controlled by a spiral spring which is preset to give the requisite pressure on the guides according to the mass to be decelerated. Since the load on the guides can be controlled, the possibility of the jaws seizing on the guides or the car being distorted is eliminated. With this type of gear the retarding force is practically constant as also is the rate of deceleration.

**Governor Rope Carriers.** Several different forms of rope carriers are in use, but the principle is the same in each case. They all perform the functions of attaching the governor rope to the car frame under normal running conditions, and of detaching the rope from the car when the governor jaws grip the rope.

One type is shown in Fig. 168 in which a stop, secured to the rope, is held between two clamps *A* and *B*, these being fixed to the car framework. The top clamp is free to turn

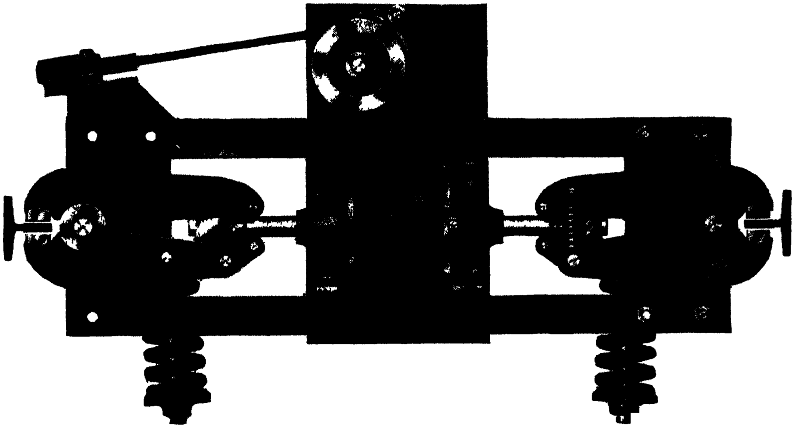


FIG. 167. WEDGE-CLAMP SAFETY GEAR
(*Express Lift Co. Ltd.*)

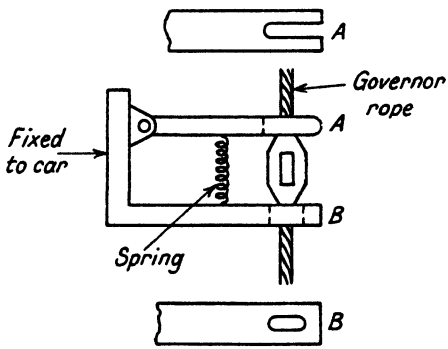



FIG. 168. GOVERNOR ROPE CARRIER

upwards and is normally held against the rope stop by the tension of a spring. When the governor jaws set, the pull on the rope rotates the top clamp against the spring tension and the rope stop is jerked free of the carrier.

Another safety rope release, known as a torpedo rope release,

is shown in Fig. 169. A $\frac{1}{2}$ in. dia. steel pin passes lengthwise across a recess in one face of the "torpedo," whilst pressure is brought to bear on the opposite face by an adjustable spring in a steel cup. The spring pressure is adjustable from zero to a maximum when a pull of 500 lb. is required on the rope in order to release.

**Governors.** It will be gathered from the foregoing that the object of a governor is to cause the safety gear to operate, if

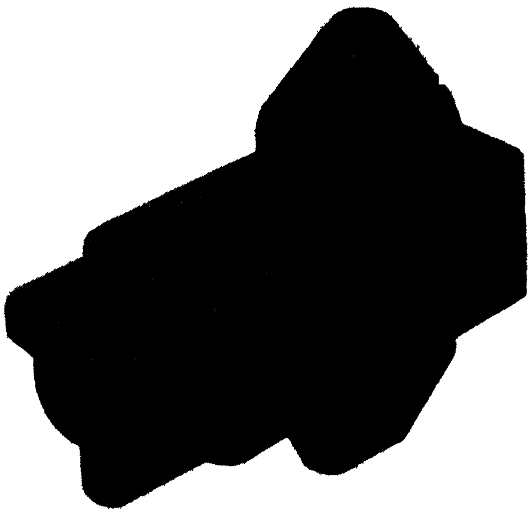


FIG. 169. TORPEDO ROPE RELEASE
(*Dewhurst & Partner, Ltd*)

from any cause the speed of the car exceeds its normal maximum speed by more than a certain predetermined value. In addition to operating the safety gear, the governor is generally arranged to cut off the control circuit before or at the same time that the safety gear sets. It is recommended that a governor be fitted to all power-driven lifts which have travels in excess of 35 ft. With the greater use of high-efficiency gearing a governor has become a necessity, since a modern lift will accelerate under conditions which the older self-sustaining gears would not permit. Car speed governors should be set so as to cause the application of the safety gear

at a speed not less than 15 per cent above the contract speed and at not more than the tripping speeds in the table below.

GOVERNOR MAXIMUM TRIPPING SPEEDS

| Contract Speed in ft. per min. | Maximum Governor Tripping Speed in ft. per min. |
|---|---|
| 0–125 | 175 |
| 150 | 210 |
| 200 | 280 |
| 250 | 337 |
| 300 | 395 |
| 350 | 452 |
| 400 | 510 |
| 500 | 625 |
| 600 | 740 |
| 700 | 855 |
| 800 | 970 |

No governor should be required to trip at a speed less than 140 ft. per min., and with the instantaneous type gear, should trip at a speed not above 200 ft. per min. If counterweight safety gear is provided, this may be operated by the same governor and governor rope used to operate the car safety gear. Provision should be made to cause the counterweight gear to be applied at a speed in excess (not more than 10 per cent) of that at which the car safety gear applies. The governor ropes which should be not less than $\frac{5}{16}$ in. in diameter should run free of the governor jaws during normal operation of the lift, and it is recommended that the governor gears have self-lubricating bearings which do not require frequent attention. The machine room is probably the best, and is certainly the most usual, location for the governor. Several different types of overspeed governors are available for lifts, but they are almost all of the centrifugal pattern, having either a vertical or horizontal governor shaft.

A geared vertical shaft governor is shown in Fig. 170. As the car speed increases, the balls open and raise the operating plate against the spring tension and thus causes the jaw to grip the rope.

Fig. 171 illustrates a governor of the horizontal shaft pattern

with the weights secured to the governor sheave and revolving in a vertical plane. As the speed rises, the rotating diameter of the weights increases due to centrifugal force operating against the pull of two equalizing springs. When a speed of,

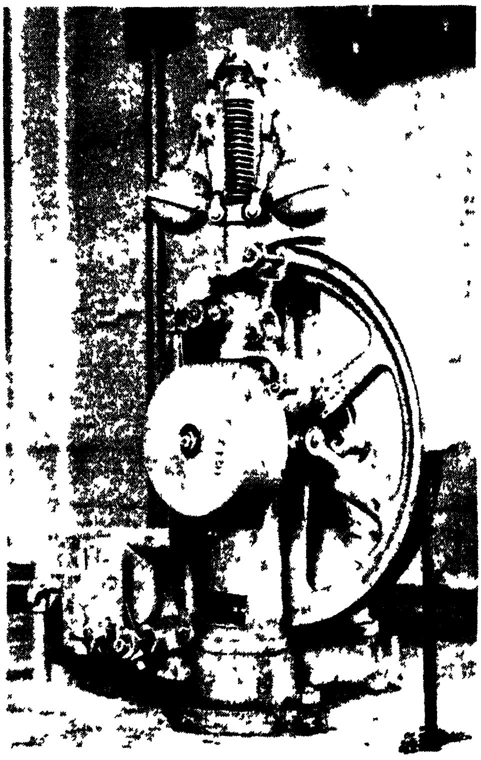


FIG. 170. VERTICAL SHAFT GOVERNOR
*(By courtesy of the Postmaster-General)*

say, 10 per cent, in excess of the maximum speed is attained, the weights open the control switch shown at the right of the illustration, and thus cut off the control circuit. If the speed continues to rise to, say, 20 per cent above the maximum speed, the weights open still further, and release the pawl which normally holds the governor jaws clear of the governor rope. The tension of the two springs at the left-hand side of the

illustration then pulls the jaws into contact with the rope and causes the safety gear to operate.

**Flexible Guide Clamp Safety Gear.** This is a further type of safety gear sometimes employed on high-speed lifts and, when operated, applies a constant retarding force to the car's motion. The gear is illustrated in Fig. 172 and consists of two clamps, one for each guide, bolted to the bottom member of the car

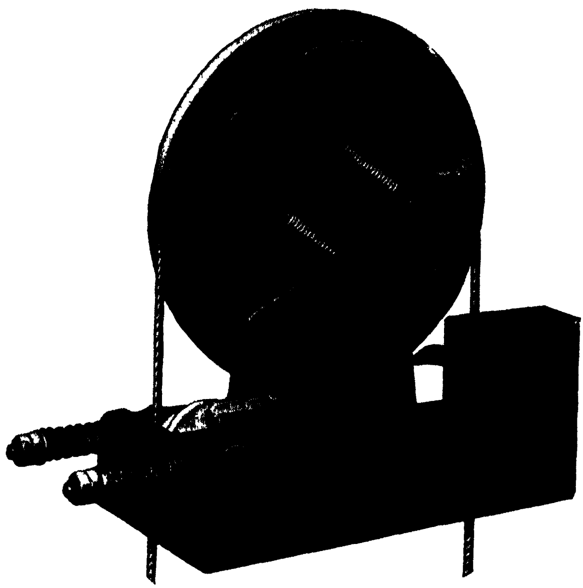


FIG. 171. AUTOMATIC SPEED GOVERNOR AND SWITCH
(*J. & E. Hall, Ltd.*)

frame, the wedge-shaped jaws of each clamp being connected by a system of rods and linkages to the governor rope. Each clamp has two of these wedge-shaped steel jaws to grip the guide and a heavy flexible spring to regulate the pressure exerted by the jaws. When the car's downward speed exceeds a predetermined value, both clamps operate simultaneously by direct pulls on the jaws, which thus grip the guides to bring the car to a swift, sliding stop. When the cause of the overspeed has been corrected the safety gear may be released by running the car up a few inches. This reverses the wedging action, and

the safety jaws slide back in their ready position without the use of a winding wrench. This gear requires a pull on the governor rope of less than 3 in., and the maximum speed which the car can attain before the jaws take hold is thereby reduced —an important feature in the operation of safety gear for high-speed lifts. After the safety jaws touch the guide, the final stopping of the car is independent of the governor and governor rope. This safety gear cannot be released from the car, unless

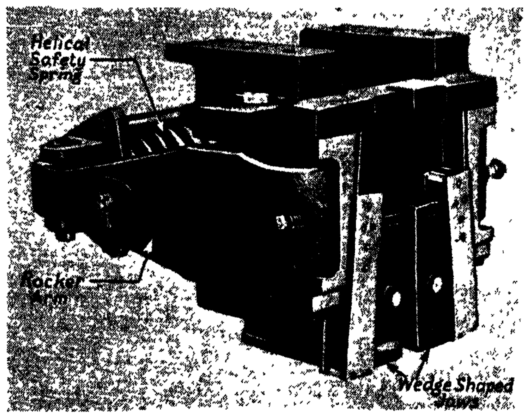



FIG. 172. FLEXIBLE GUIDE CLAMP SAFETY GEAR
(*Waygood-Otis, Ltd.*)

the hoisting machine is in a condition to lift the car and thus the danger of a premature release is minimized. The use of this gear ensures that the car floor is solid and free of wrench holes and cover plate.

**Safety Gear Stopping Distances.** The stopping distance with the instantaneous type safety gear is very small but the stopping distances of the wedge clamp types and the flexible guide clamp type are much greater. The maximum and minimum distances for the latter types are as stated in the table on p. 235, the stopping distance being defined as the actual slide, as measured by the marks on the guides.

**Car and Counterweight Clearances.** Clearances must be allowed for the car at the top and bottom of the well so as to permit it to slow down if, for any reason, a terminal floor is over-run and the final terminal switch is operated. Suitable top and

bottom clearances must also be provided for the counterweight.

*The top car clearance* is the distance between the uppermost part of the car or any rigid attachment thereto and the nearest fouling point of the overhead structure, when the car is level with the top landing.

*The bottom car clearance or overtravel* is the distance, including the buffer compression, between the lowermost part of the car or any rigid attachment and the top of the car buffers, when the car is level with the bottom landing.

*The top counterweight clearance* is the shortest vertical distance between any part of the counterweight assembly and the nearest part of the overhead structure when the car is level with the bottom landing.

*The bottom counterweight clearance or overtravel* is the shortest vertical distance including any buffer compression between any part of the counterweight assembly and any fixed obstruction below it when the car is level with the top landing.

SAFETY GEAR STOPPING DISTANCES

| Governor Tripping Speed in ft. per min. | Stopping Distance Minimum | | Stopping Distance Maximum | |
|---|---|---|---|---|
| | ft. | in. | ft. | in. |
| 175 | 0 | 6 | 1 | 3 |
| 200 | 0 | 6 | 1 | 4 |
| 250 | 0 | 8 | 1 | 7 |
| 300 | 0 | 10 | 2 | 0 |
| 350 | 0 | 11 | 2 | 4 |
| 400 | | 1 | 2 | 9 |
| 450 | | 3 | 3 | 4 |
| 500 | | 6 | 4 | 0 |
| 550 | | 8 | 4 | 7 |
| 600 | | 11 | 5 | 3 |
| 650 | 2 | 2 | 6 | 0 |
| 700 | 2 | 6 | 6 | 9 |

The clearances allowed, in practice, should be as stated on page 236.

(*a*) *Clearances for car and counterweight when spring buffers are employed.*

| Contract Speed Ft. per. min. | Minimum Bottom Clearance for Car and Counterweight | | Minimum Top Clearance for Car and Counterweight | |
|---|---|---|---|---|
| | ft. | in. | ft. | in. |
| 0–100 | 1 | 1 | 1 | 6 |
| 101–200 | 1 | 4 | 2 | 0 |
| 201–300 | 1 | 8 | 2 | 6 |

(*b*) *Clearances for car and counterweight when oil buffers are employed.*

To ensure satisfactory bottom clearances the depth of the pit should be at least the sum of the following—

(1) The overall length of the fully extended car buffer used.

(2) The distance between the upper surface of the car floor and the lower surface of the buffer striking plate.

(3) Six inches.

Where the bottom car clearance is greater than the minimum specified above then the top counterweight clearance must be increased by a similar amount.

The top car clearance should be at least the sum of the following—

(1) The distance between the counterweight buffer and its buffer block, which should be at least 6 in.

(2) The stroke of the counterweight buffer.

(3) Twelve inches.

(4) The counterweight buffer stroke corresponding to the governor tripping speed less one half the stroke of the counterweight buffer used.

Item (4) may be omitted if provision is made to eliminate the jump of the car at counterweight buffer engagement.

The top counterweight clearance should be at least the sum of the following—

(1) The distance between the car buffer and the buffer striking plate which should be at least 6 in.

(2) The stroke of the car buffer used.

(3) Six inches.

(4) The car buffer stroke corresponding to the governor tripping speed less one half the stroke of the car buffer used.

Item (4) may be omitted if provision is made to eliminate the jump of the counterweight at car buffer engagement.

*The top overtravel* is defined as the distance provided for the car floor to travel above the level of the top terminal landing when the car is stopped by the normal terminal stopping switch.

*The bottom overtravel* is the distance the car floor can travel below the level of the bottom landing when the car is stopped by the normal terminal stopping switch.

**Normal Terminal Stopping Switches.** Every electric lift should be provided with an upper and a lower normal terminal stopping switch, these being arranged to stop the car automatically within the top and bottom overtravels, from the contract speed. These switches act independently of the normal operating device, the ultimate or final terminal stopping switches, and the buffers. They may be fitted to the car and be operated by a ramp in the well, or in the well and operated by a car ramp, the former usually for high speeds and the latter for low speeds. Alternatively, the switches may be fitted in the motor room, but in all three cases they must be operated by the movement of the car. In some switches the contacts are of the knife pattern and, in others, of the plate contactor type.

A normal terminal stopping switch of the knife pattern for cutting off the control circuit and suitable for well or car mounting is shown in Fig. 173 and one of the contactor type in Fig. 174.

Fig. 175 depicts a terminal stopping switch arranged for mounting in the machine room.

On high-speed lifts it is usual to install slowing limit switches which automatically reduce the speed of the car before the terminals are reached. The slowing down is accomplished by means of a multiple slowing switch, the contacts of which are opened by ramps fitted in the well. An example of a switch of this type is shown in Fig. 176.

**Final Terminal Stopping Switches.** These are arranged to stop the car automatically within the top and bottom clearances, independently of the normal operating device and the normal terminal stopping switches, but with the buffers operative. A normal terminal stopping switch and a final terminal stopping switch of the type shown in Fig. 174, both mounted

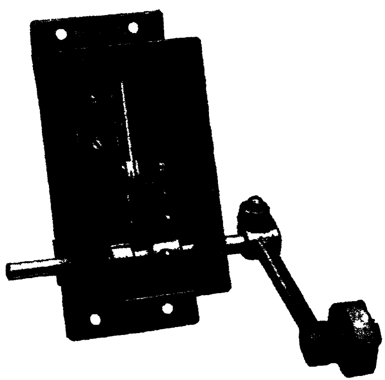


Fig. 173 Terminal Stopping Switch
(Cover removed)
(J. & E. Hall, Ltd.)

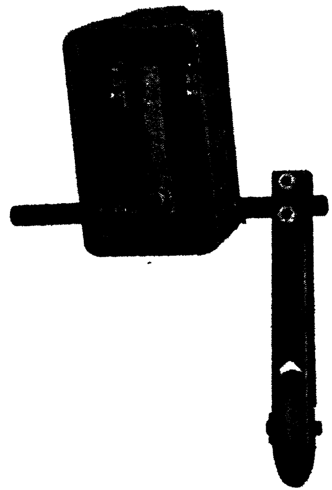


Fig. 174.
Terminal Stopping Switch
(Dewhurst & Partner, Ltd.)

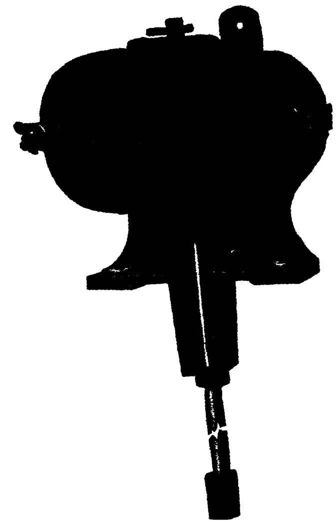


Fig. 175. Terminal Stopping Switch
(Wm. Wadsworth & Sons)

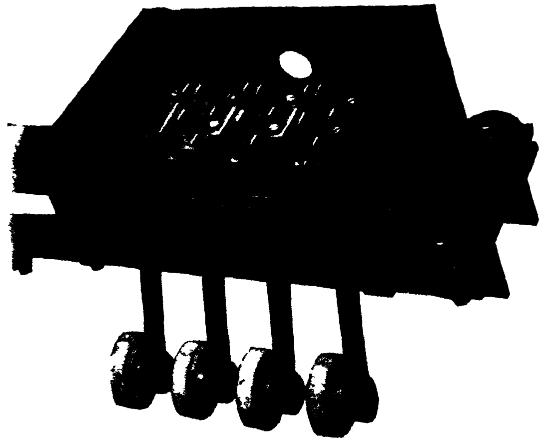


Fig. 176. Multiple Slowing Switch
(With cover removed)
(*J. & E. Hall Ltd.*)

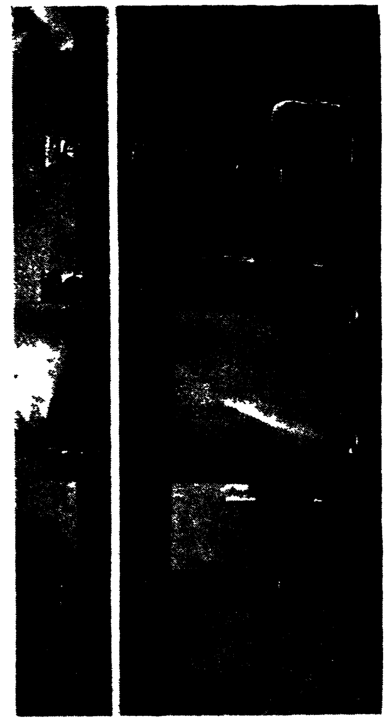


Fig. 177. Terminal and Final Limit Switches
(*Marryat & Scott*)

in the well, are shown in Fig. 177. The switches should be so arranged that the opening of the switch takes place with the car as close to the terminal floor as practicable without interfering with the normal operation of the lift. With spring buffers, however, the switch should open before the buffers are engaged. After operating, these switches remain open until the car has been moved by hand winding to a position within the limits of normal travel. These switches are operated by the movement of the car in the well and the general practice is for them to open simultaneously both the control and motor circuits.

With variable voltage control the operation of either final limit switch should cause the lift motor to exert its full dynamic braking effort with the motor field winding energized and the motor generator running.

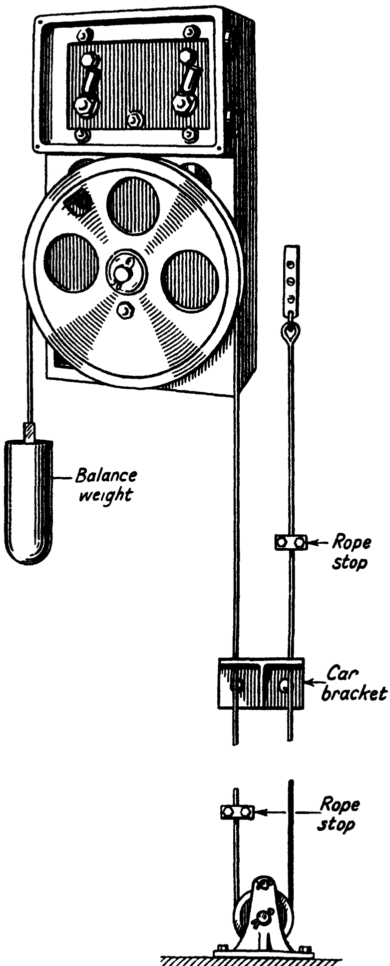



FIG. 178. FINAL TERMINAL SWITCH
(*Wm. Wadsworth & Sons*)

One method of operation is shown in Fig. 178, this being used for speeds up to 400 ft. per min. A steel flyrope, passing round the switch operating drum, is anchored in the machine room at one end and has a balance weight attached to the other end. Rope stops are secured to this rope at the top and bottom limits of travel, and a bracket, fixed to the car, slides freely over the rope. When the car bracket comes into contact with either rope stop, the

drum is rotated and the switch opened. This type should have an automatic safety switch which will stop the lift if the flyrope breaks. A final stopping switch is shown in Fig. 179. This is for a 3-phase supply with rectified control circuit.

Although a rope-driven mechanically-operated final stopping switch is satisfactory at low speeds, it is not suitable for high-speed variable-voltage gearless drives for which an electrically-

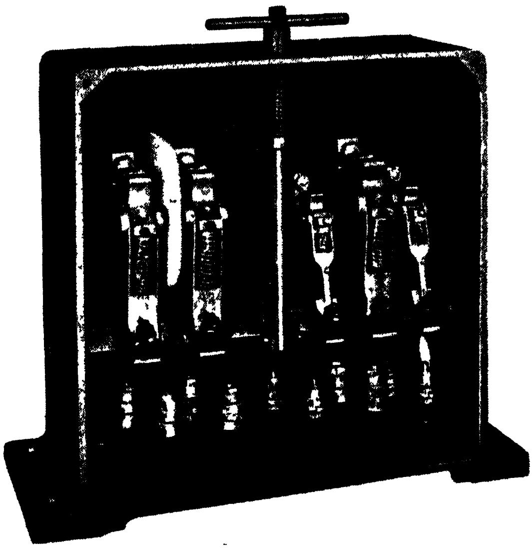


FIG. 179. FINAL STOPPING SWITCH
(Cover removed)
(*Etchells, Congdon & Muir*)

operated device is required. With high speeds it is necessary to provide protection at a point some distance in advance of the terminal floors and also to keep the machine energized in order to reach the floor safely at levelling speed. For high speeds the final stopping switch is fitted in the well and is operated directly by the gear in the event of overtravel. The operation of this switch trips both the reversing contactors and the line contactor and so cuts off current to the motor and applies the brake. Hence there must be simultaneous failure of two contactors to create an unsafe condition. To eliminate

the possibility of welding of contacts they are usually carbon to copper. Some manufacturers fit this direct-action final switch on slow-speed lifts (instead of a rope-driven limit switch) as well as on high-speed installations.

## BUFFERS

In the event of the final terminal stopping switch operating, and the car not coming to rest within the clearance provided, either the car or counterweight will make contact with buffers which lessen the impact. Two buffers are fitted in the well under the car, these being placed symmetrically with respect to the centre of gravity of the car, and, in addition, one or two

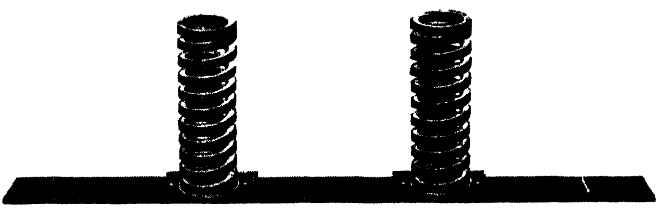


FIG. 180. SPRING BUFFERS MOUNTED ON FIXING PLATE
Note registration piece for tee guides
(*Express Lift Co. Ltd.*)

buffers are fitted under the counterweight. These buffers therefore constitute the final emergency device.

**Spring Buffers.** For speeds up to 300 ft. per min., preferably not exceeding 200 ft. per min., buffers may consist of helical springs of the type shown in Fig. 180; or volute springs, an example of which is reproduced in Fig. 181. The rubber buffers shown are used with lifts of contract speed not exceeding 75 ft. per min. or any service lift. Their size must be such that they are capable of stopping the loaded car from contract speed without permanent distortion, and the maximum rate of retardation with 150 lb. in the car should not exceed 80·5 ft. per sec. per sec. All spring buffers have an increasing rate of deceleration as the spring is compressed.

**Oil Buffers.** These are fitted for car speeds above 300 ft. per min., the piston stroke depending upon the maximum car speed. The minimum total stroke is calculated upon an average retardation of 32·2 ft. per sec. per sec., at 115 per cent contract

speed. The maximum retardation, based on 115 per cent contract speed, should not exceed 80·5 ft. per sec. per sec., i.e. $2\frac{1}{2}$ times the retardation due to gravity. These buffers are designed so that the rate of deceleration is as nearly as possible constant.

SPRING RETURN OIL BUFFER. The oil buffer usually employed for lift cars is of the spring return type. The following

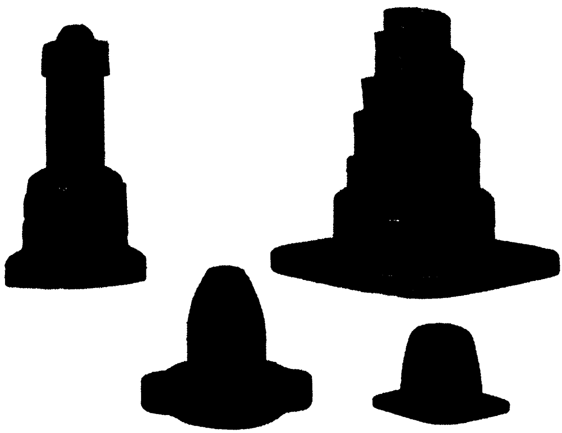


FIG. 181. TYPES OF BUFFER
*(Marryat & Scott)*

is a brief description of Messrs. Waygood-Otis's spring return oil buffer, a drawing of which is shown in Fig. 182 and an illustration in Fig. 183. When the car strikes the buffer, a spring in the upper part of the piston rod is compressed, and acts as a cushion for the rod and piston, thus preventing them from receiving too sudden a blow. A rubber cushion, at the top of the buffer, also further deadens the blow. As the piston starts its downward movement, the oil beneath it is forced from the cylinder into the outer casing, and also into the upper chamber, through a series of holes in the cylinder. The area of the upper holes is large, and therefore little resistance is offered to the flow of oil during the initial piston movement. Hence, the piston accelerates fairly rapidly and takes up the running

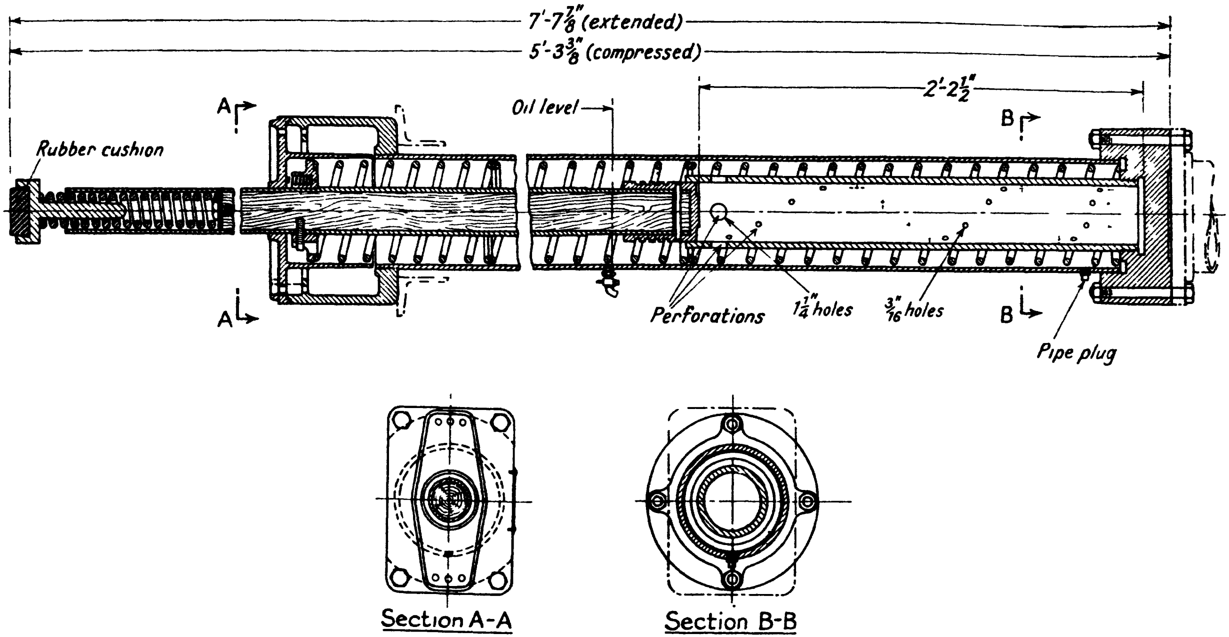



FIG. 182. SPRING RETURN OIL BUFFER
28 in. stroke
(*Waygood-Otis, Ltd.*)

speed of the car. Any back pressure due to the inertia of the piston and rod in starting is absorbed by the spring. As the piston descends, the number and size of the holes below the piston become less and the restriction to the oil flow increases.

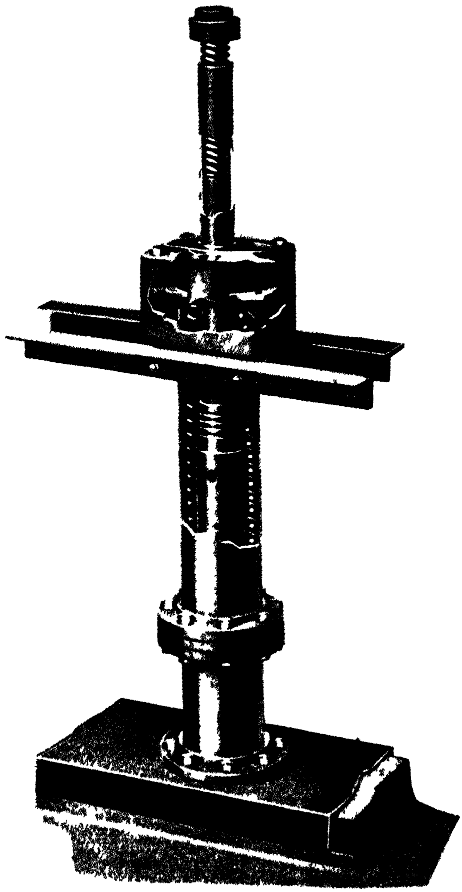


FIG. 183. OIL BUFFER
(Spring Return)
(*Waygood-Otis, Ltd.*)

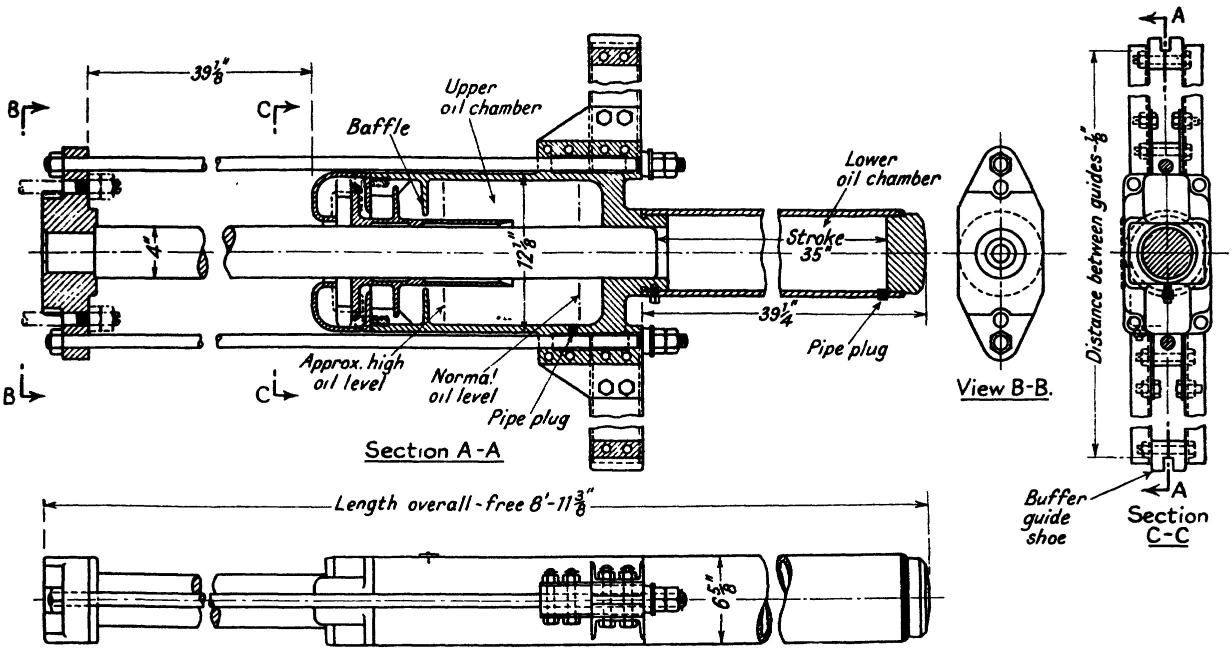



FIG. 184. GRAVITY RETURN OIL BUFFER
35 in. stroke
(*Waygood-Otis, Ltd.*)

When the piston has closed the last hole the car comes to rest.

As soon as the car is moved away, the piston is forced upwards by the large spring, and the moving parts are restored to their normal position, whilst at the same time the oil flows back into the cylinder.

GRAVITY RETURN OIL BUFFER. The following description relates to Messrs. Waygood-Otis's oil buffer, shown in Fig. 184. This type is generally used as a counterweight buffer, as it can be attached to the bottom of the counterweight and so form a useful part of the counterweight itself. The cylinder consists of upper and lower oil chambers, and when the buffer is stopped by striking a block at the bottom of the well, the oil contained in the lower chamber is forced into the upper one, through an area formed by longitudinal slots in the plunger and its guiding sleeve. These slots are of varying lengths and so arranged as to provide a reasonably constant retardation of the moving counterweight. By the time the longest slot is covered in the sleeve, the energy of the counterweight has been entirely absorbed. Any further downward movement of the plunger is prevented since the oil has no additional outlet. The cover of the upper oil chamber is provided with baffles to prevent the oil from being sprayed out when the buffer is in operation.

**Guarding.** Lift well enclosures should be provided and should extend on all sides from floor to floor or stair to stair. If the enclosure is of the open type any mesh used should not be greater than 1¼ in., but if the clearance between the enclosure and any moving part of the lift is less than 2 in. the mesh should be not greater than ½ in. square and of wire not smaller than 20 s.w.g. Counterweight guards of wire mesh should be provided, except where the use of compensating cables makes this impracticable. One of these guards is fitted at the position where the car and counterweight pass each other and another in the pit, extending to a height of about 7 feet above the pit floor. They eliminate the possibility of injury to maintenance engineers when travelling on the car or working in the pit respectively. A counterweight guard fitted to the top of a car, local control buttons, and telephone for the maintenance staff are shown in Fig. 185.

**Gates.** Many accidents have been caused in the past by persons' feet or arms being crushed when protruding through

the space between gate pickets, the usual spacing of which, with ordinary type gates, is about 5 in. Consequently, gates for landings and the car are now invariably of the close picket type usually known as mid-bar gates, in which the distance between adjacent pickets is not more than $2\frac{1}{2}$ in.

A practice which is sometimes adopted on older lifts to obviate the need to replace completely wide-spaced picket

FIG. 185. COUNTERWEIGHT GUARD
(*Marryat & Scott*)

gates, is to fit short mid-bars about 12 in. long to the bottom of the gates to prevent toes from being trapped, and also a safety plate near the gate handle so that it will be impossible for an arm to reach through the gate to the car push button plate.

**Gate or Door Locks.** The locks fitted to the landing and to the car entrances comprise one of the most important safety items in a lift installation.

The landing gate or door locks should be such that the gate or door cannot be opened from the landing unless the car is at that particular landing and also that the car cannot be

moved unless all landing gates or doors are closed and locked. The lock must therefore comprise a mechanical lock which is capable of being released only when the car is at the landing, and in addition, an electric interlock, the contacts of which are open when the landing gate or door is open. It is thus impossible for a landing opening to be left unprotected when the car is away from that landing.

The car gate or door lock consists of an electric switch which

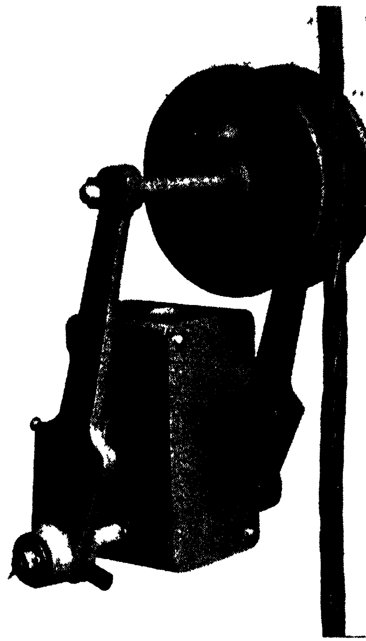


FIG. 186. SLACK ROPE SAFETY SWITCH
(*Dewhurst & Partner, Ltd.*)

opens its contacts immediately the gate or door is opened, thus ensuring that a lift cannot move unless the car gate is closed.

**Landing Gate or Door Clearance.** Accidents have occurred due to persons standing in the space between the landing and car gates whilst opening one of these gates and the car then being called to another landing. To prevent this happening the distance between the well side of the landing gate or door and

the well edge of the landing threshold should not exceed 4 in. for hinged doors or $2\frac{3}{4}$ in. for sliding doors or gates.

**Car Apron.** On many modern lifts the doors begin to open when the car enters the levelling zone, which may be about 12 in. from the floor. To prevent a person's foot from being trapped between the landing and the descending car during this levelling period, an apron should be fitted to the car platform of such a depth that no gap exists at any time when a landing door is opening.

**Car Emergency Exit.** This should be fitted with an electric switch, which will cut off the supply to the lift when the exit door is open and thus prevent the lift from moving when a person may be using the exit and is consequently then in an unsafe position.

**Emergency Stop Push.** All passenger operated lifts, except those fitted with sliding doors on both the car and landing, should be fitted with a stop push in the car, momentary pressure on which will bring the car to rest.

To provide the maintenance engineer with protection when working on the top of the car an emergency stop switch should be fitted on the car top.

**Slack Rope Safety Switch.** This switch is fitted to drum-drive lifts and automatically cuts off the supply to the motor if the car meets an obstruction and the ropes become slack. This is shown in Fig. 186.

**Wiring.** From the safety aspect it is essential that all electric cabling and wiring be carried out in a sound and efficient manner and be in accordance with the Institution of Electrical Engineers "Regulations for the Electrical Equipment of Buildings." The following regulations affect lifts and should be noted.

Reg. 209 (B). All cables, other than travelling cables installed for any purpose in a lift or hoist shaft, shall normally be armoured, or enclosed in steel conduit, duct or trunking, or copper conduit, or be of the mineral-insulated metal-sheathed type or of the aluminium-sheathed type.

Reg. 214 (A). This indicates that if the travelling cable contains any conductor operating at a voltage in excess of 30 a.c. or 50 d.c., no other conductor in that cable shall be used in any system operating at a voltage lower than 30 a.c. or

50 d.c. or in any radio, telephone, bell and call or sound distribution circuit.

REG. 315. This requires that there shall be, preferably in the machine room, efficient means whereby all voltage can be cut off from the motor, controller and automatic circuit breaker. If the means of isolation is not in the machine room, provision shall be made for it to be locked in the OFF position.

The usual method of effecting this is by a separate switch in the machine room controlling the incoming mains to the lift. If the machine room houses several lifts, the incoming mains may be terminated at a distribution board with a separate set of removable fuses for each lift circuit. Alternatively, a separate switch for each lift supply may be fitted in the machine room near each lift.

REG. 402. This specifies that the metal framework of the motors, controllers, switchgear, electrical equipment in the car, and the electric conduits shall all be effectively earthed.

REG. 404. This requires that the car metal framework shall be bonded and connected to earth.

The best method of achieving this is by connecting the car frame to the earthing system of the metalwork of the machine room via a conductor in the travelling cable.

REG. 407 (B). This specifies that the cross-sectional area of the earth conductor in the travelling cable shall be equal to that of the current-carrying conductors.

**Factories Acts.** Other regulations affecting the safe working of lifts are in Appendix I.

## CHAPTER XIII

### FLOOR LEVELLING

ACCURATE levelling of the car at the various landings is an essential to good lift service; with passenger lifts the danger of passengers tripping when entering or leaving the car must be minimized, whilst with goods lifts, particularly if trucks or trolleys are carried, easy entry and exit are desirable. Inaccurate levelling also results in "inching" of the car to obtain better final levelling, and a consequent increase in energy consumption and wear on the controller contacts. A method used to counteract the difficulties due to minor inaccuracies in floor levelling, without actually re-levelling the car, is shown in Fig. 187. This hinged ramp greatly facilitates the passage of small-wheeled trucks by bridging over the bottom car and landing gate tracks and the gap normally existing between the landing sill and the car floor. It can also be seen how the ramp forms a toe-guard when the gate is closed.

With simple car switch control, stopping is performed by the operator returning the car switch to the centre position when the car is at the appropriate distance from the floor. The centring of the car switch cuts off the supply and causes the brake to operate, in the case of a single-speed lift; but if a two-speed motor is employed, an intermediate car switch position enables the final stopping to be performed from slow speed. The accuracy of levelling therefore depends upon the judgment of the operator in returning the switch to the slow and stop positions at the correct moments. In some forms of car switch control, stopping is performed automatically by centring the car switch when the car has passed the floor immediately preceding that at which a stop is desired. The levelling, in these cases, is dependent upon the settings of the automatic slowing and stopping devices, and the adjustment of the mechanical brake.

Several methods are employed to stop an automatic lift at the desired landing, the efficiency of the schemes depending upon the accuracy of timing of the automatic slowing and

stopping devices in reducing the car speed and cutting off the motor supply respectively before the operation of the mechanical brake.

Besides good brake adjustment and accuracy of setting of the slowing and stopping equipment, another factor which

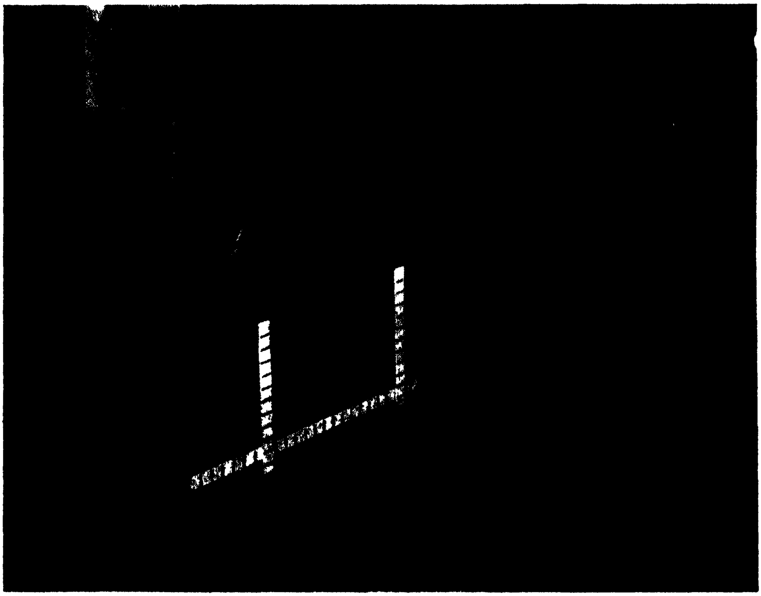


FIG. 187. CAR LEVELLING RAMP
(*Marryat & Scott*)

affects levelling is the variation of load in the car. Some small consideration will show that the distance required for the stopping of the car, after the application of the brake, will be greater if full load is being lowered than with an empty car, on the assumption that the brake retarding force is the same in each case. Similarly, the distance in which the car will come to rest when raising full load is less than when raising an empty car. To ensure good levelling it is essential that the distances travelled by the car after the application of the brake should be the same, irrespective of load, and to effect this it is desirable to arrange that the final cut-off speed of the car is slightly

higher when lifting full load than when lifting an empty car. In other words, the speed should slightly increase with the load, and this means a rising motor characteristic. This characteristic, whilst unstable with an ordinary shunt machine,

FIG 188. DIRECTION SWITCH RAMP
(*Marryat & Scott*)

may readily be obtained with variable voltage control. The rising characteristic is only required at the slow levelling speed, which is from about one-sixth to one-twentieth of the maximum speed.

This may be illustrated by considering the following two conditions.

(*a*) *The fully loaded car travelling upwards.*

Let the contract load and the weight of the car be 1 200 lb. each and the weight of the counterweight 1 800 lb. When the power is cut off by the stopping switch, the car is slowed down by the application of the brake and the decelerating force of the moving system. If the brake retarding force and the frictional resistances are constant, the distance moved after the power is cut off depends upon the retardation due to the moving car and counterweight.

$$\text{The retarding force} = \frac{\text{total mass} \times \text{retardation}}{g}$$

$$\therefore \qquad 600 = \frac{4\,200 \times f_1}{32}$$

and $f_1 = \dfrac{32}{7}$ ft. per second per second.

(*b*) *The car* $\frac{3}{4}$ *loaded travelling upwards.*

Under this condition the motor is exerting approximately half of its full load torque.

$$\text{The retarding force} = \frac{3\,900 \times f_2}{32}$$

$$\therefore \qquad f_2 = \frac{300 \times 32}{3\,900} = \frac{32}{13} \text{ ft. per second per second.}$$

For accurate levelling the distance $s$ moved after the power is cut off must be the same in each case.

But $v_1^2 = 2f_1s$ and $v_2^2 = 2f_2s$.

where $v_1$ and $v_2$ are the respective levelling speeds in the two cases.

$$\therefore \qquad \frac{v_1}{v_2} = \sqrt{\frac{f_1}{f_2}} = \sqrt{\frac{13}{7}} = 1{\cdot}36.$$

Hence the levelling speed with contract load (motor at full load) should be 36 per cent greater than that with $\frac{3}{4}$ contract load (motor at $\frac{1}{2}$ load), i.e. the levelling speed should increase with the load.

The principal methods used for automatically slowing, stopping, and levelling lift cars are as follows.

**Direction Switches.** Direction switches, sometimes used on single-speed automatic lifts, are either single- or two-way switches fitted in the well, one at each landing. A two-way switch is necessary for each intermediate landing (one way for each direction of travel) but a single-way switch only is required at each terminal landing. Each switch is operated by a ramp, fitted to the car, when the car reaches the appropriate landing. When passing landings in the upward direction, the switches are in turn operated, and thereby change the floor relay connexions from the UP contactor to the DOWN coil ready for operation during the down direction. Hence each direction switch which is below the car is connected to the DOWN contactor coil. Similarly, during the downward travel the ramp moves the switch operating arms to the up direction, and therefore all direction switches above the car are joined to the UP contactor coil. When the car is stationary at a landing the corresponding direction switch is in the centre or OFF position, and current is thus cut off from the main contactor coil. Each terminal direction switch is opened and closed when the car arrives at and leaves the terminal landing respectively. A typical operating ramp is shown in Fig. 188, the top throw-in horn engaging the switch arm roller during the upward journey, and the bottom horn returning the roller to its original position during the downward journey. When the roller is in contact with the centre vertical track, both contacts of the switch are disconnected. An intermediate floor direction switch is shown in Fig. 189.

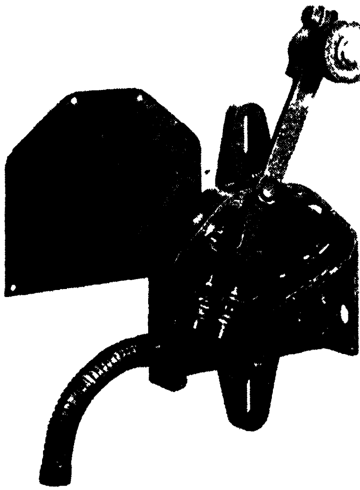


FIG. 189. DIRECTION SWITCH
(Intermediate floor)
(*Marryat & Scott*)

**Floor Selectors.** A floor selector switch for installation in the

motor room, as shown in Fig. 190, is frequently used to perform the functions of slowing and stopping. The slowing and stopping contactor coils are controlled by a system of contacts operated by selector arms fixed to a shaft, on one end of which is keyed a drum, the drum being driven from the car by a steel

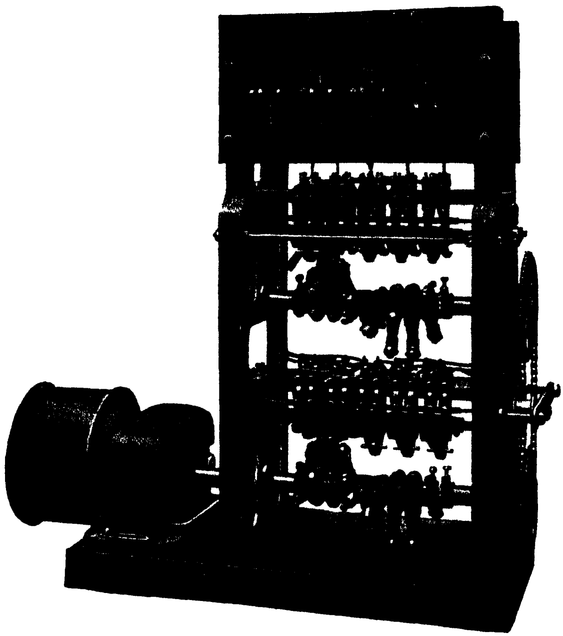


FIG. 190. FLOOR SELECTOR FOR AUTOMATIC LIFT
(*Wm. Wadsworth & Sons*)

flyrope. Hence the selector arms rotate in unison with the movement of the car in the well, and open-circuit the slowing and stopping contactor coils when the car is at the appropriate positions in the well. For each intermediate floor served, two switches and two operating arms are required for stopping in the two directions, whilst only one switch and one arm are necessary for each terminal floor. With two-speed motors, additional switches and selector arms are necessary for each floor so as to perform the slowing down prior to the operation of the stopping switches.

Another type of floor selector for installation in the motor room is shown in Fig. 191 and consists of two copper drums insulated from one another. These drums are rotated by the motion of the car, being driven through gearing from a pulley which is connected to the car by means of a flat steel tape. In

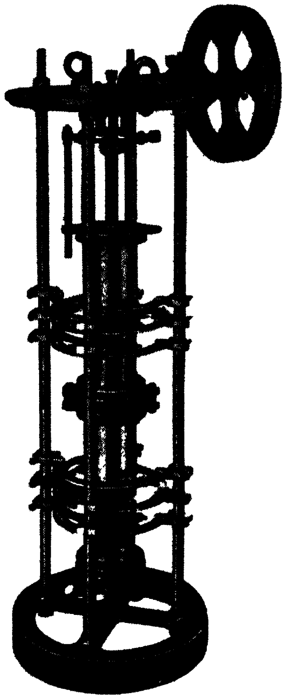


FIG 191
TWO-SPEED FLOOR SELECTOR
(*Etchells, Congdon & Muir*)

FIG. 192 FLOOR SELECTOR
(*By courtesy of H M Postmaster-General*)

addition to their circumferential movement, the drums rotate on a screw which causes them to travel in the vertical direction. The result is that a high degree of accuracy is obtained, a movement of about $\frac{1}{4}$ in. on the drum being obtained for every 1 in. travel of the car. For tall buildings, the dimensions of the selector increase vertically and not horizontally, and for ten floors and two speeds the height is about 4 ft.

Another floor selector used for speeds of 300 ft. per min. and above is shown in Fig. 192. This is mechanically driven from the car by a toothed steel tape; ensuring accurate and positive operation. The vertical movement of the selector crosshead therefore corresponds on a smaller scale to the movement of the car in the well. In addition to slowing down and stopping at the required floor this selector controls the car and landing signals and indicators and the opening of the car door. Distributed up and down the selector are "floor bars" corresponding to the floor served, and on each bar is a group of electrical contacts. The sliding contacts are silver to impregnated carbon and the butting contacts silver to silver. As the crosshead is driven up and down it engages these contacts and so operates the relays which perform the various functions referred to above. For example, if the car of a collective control lift is travelling downwards at full speed and a down landing call is registered at the sixth floor, as the car passes the eighth floor position, the crosshead completes circuits which light the hall lantern at the sixth floor and extinguish the signal light in the sixth floor landing button. As the car enters the slowing zone for the sixth floor, the selector initiates the operation which slows down the speed of the car, and subsequently a levelling device on the selector takes over to level the car and open the car and landing doors. After the call has been answered, the selector extinguishes the hall lantern, lights the proper signal lights on the landings ahead and in the car. A selector of this type is used in the Waygood Otis controller described in Chapter XV.

The floor selector employed by the Express Lift Company is shown in Fig. 193, the overall dimensions of the selector being about 12 in. × 6 in. × 6 in. In addition, this selector performs the functions of establishing direction of travel, initiating stopping, and of operating car position indicators. It is a multi-contact rotary switch which can be fitted with a multiplicity of contacts and operating cams and is operated by two driving magnets which drive the cam shaft in either direction of rotation, depending on the travel of the lift. The principle of operation is similar to that adopted in telephone exchange selectors, although this selector has been specially designed to meet lift requirements. The UP and DOWN direction driving

magnets are operated by impulses received from the inductor fitted on the car, a description of which appears later in this chapter. The chart shown in Fig. 194 gives the sequence of contact operation as the selector steps one step in the appropriate direction when the car passes the inductor plates fitted in the lift well. The plates are fitted on either side of the

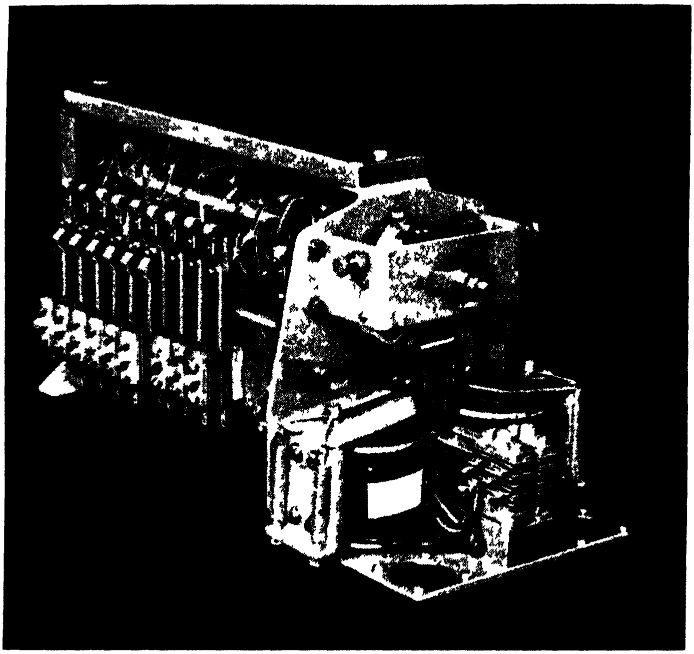


FIG. 193. FLOOR SELECTOR
(*Express Lift Co Ltd*)

floor datum line at such a distance as is required to bring the car to rest at floor level from either direction. Considering a single-speed lift to illustrate the principle of operation of the selector, one plate will be required on each side of each floor level. Three sets of contacts are provided on the selector as shown, control contacts, indicator contacts, and resetting contacts.

The circuit for driving the selector is shown in Fig. 195, the selector being impulsed by the inductor contact *ZS* which

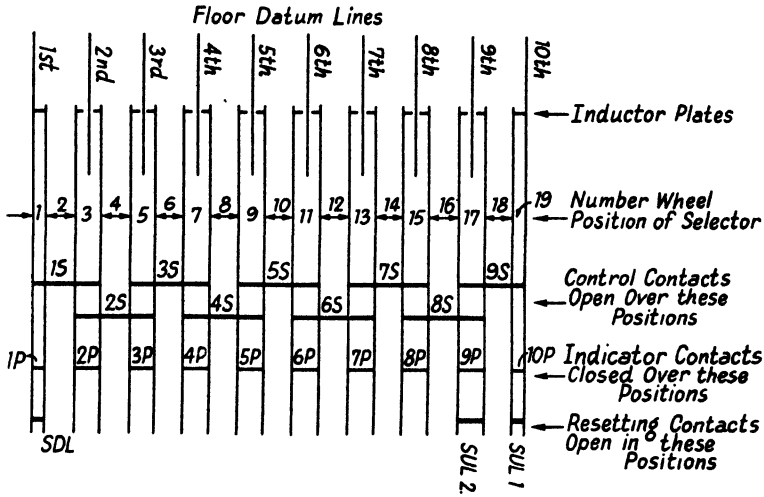



FIG. 194. FLOOR SELECTOR CONTACT SEQUENCE

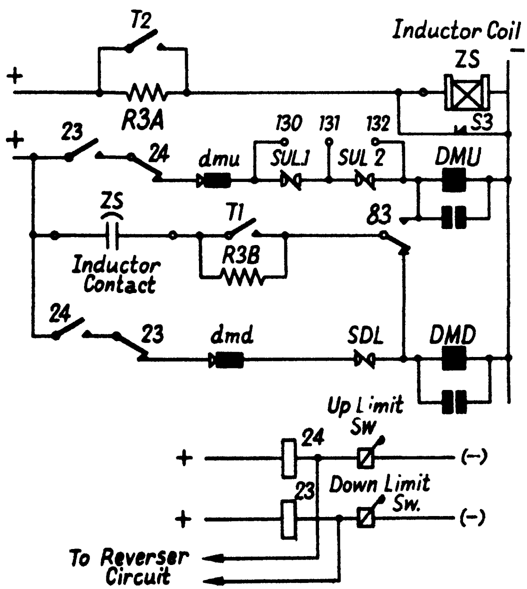



FIG. 195. FLOOR SELECTOR DRIVING CIRCUIT

closes the circuit to the UP or DOWN driving magnet *DMU* or *DMD* via change-over contact 83. Relay 83 is a change-over directional relay which is operated when the lift travels UP and remains operated until the lift reverses to travel DOWN. The resistance *R3B* in this circuit, which is inserted by contact T1 after each stop, is a protective resistance to prevent over-heating of the driving coils should the lift stop for a long period

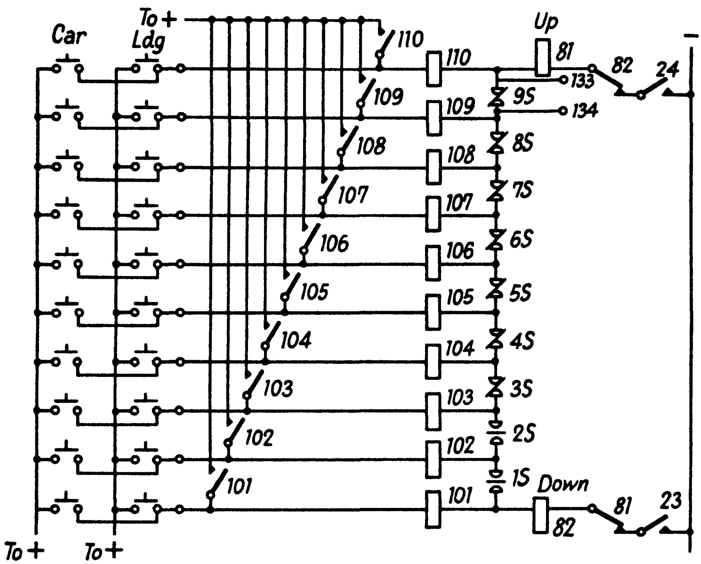



FIG. 196. FLOOR SELECTOR DIRECTION AND STOPPING CIRCUIT

with the inductor operated. Resetting is achieved by the release of relay 23 or 24 at the bottom and top floor respectively, contacts of which relay operate the UP and DOWN driving magnets via the interrupter contacts *dmu* and *dmd* and the resetting limit contacts *SDL* and *SUL*1 or *SUL*2 on the selector. The two upper resetting contacts *SUL*1 and *SUL*2 are provided in the driving magnet so that a given selector can cover two floor combinations (e.g. 9 or 10 floors). Terminals 131 and 132 are jumpered for an even number of floors and 130 and 131 for an odd number of floors. The resetting limit contacts will normally open if the selector is in sequence before 23 or 24 releases.

The directional and stopping circuit of the selector is shown in Fig. 196. At any lift position at least one control contact is open, and at floor level it will be seen from Fig. 196 that two contacts are open. Hence any call relay above the open contact is energized via the UP directional relay 81 and any call relay below is energized via the DOWN directional relay, e.g. with the car at the 4th floor the selector contacts 3S and 4S are open and this isolates the 4th floor call relay 104 and cuts off all call relays 105 to 110 from the DOWN circuit to relay 82. This enables these relays 105 to 110 to operate by pressure on a car or landing button for any floor above the 4th floor only, via the UP circuit to relay 81. Similarly, landing or car buttons below the 4th floor can only operate their respective relays via the DOWN circuit to relay 82. As the lift travels to answer a call, the relative call relay remains energized until the selector contacts on either side of its negative coil feed are opened, when the car reaches floor level. This opens the circuit to the call relay and the direction relay and stops the car. At a terminal floor, stopping is effected by the opening of the limit switches *UL* or *DL*, which also releases relay 24 or relay 23.

**Corrective Levelling Systems.** Various means have been adopted for securing accurate final levelling in which the levelling resulting from the operation of the floor selector stopping switches is corrected, if necessary, by independent means. With some of these corrective levelling devices it is possible to secure final levelling to within $\pm \frac{1}{8}$ in., irrespective of load variations or rope stretch during loading.

In one method a three-level ramp is fitted at each landing, this ramp engaging a three-position switch fitted to the car, at those landings where stops are made. If the car stops below the landing, after the floor selector switch has operated in the normal manner, the three-position switch will engage with the bottom level of the ramp. This results in the motor being restarted and run at the slow speed, in such a direction that the car travels upwards. When the switch engages with the centre level the car is correctly levelled, the motor supply is cut off and the brake applied. Similarly, if the levelling is too high, the switch on the car engages with the top ramp level and this causes the motor to run at slow speed in the opposite direction

and the car thus travels downwards until the centre cam level engages the switch, when the motor supply is cut off and the brake applied. The levelling switch, which is automatically withdrawn beyond reach of the ramp when passing landings, is of special construction and correctly engages the ramp irrespective of any car side movement due to shoe wear.

A two-position switch operating on this principle is shown in Fig. 197. This is fitted to the car, and during normal travel the

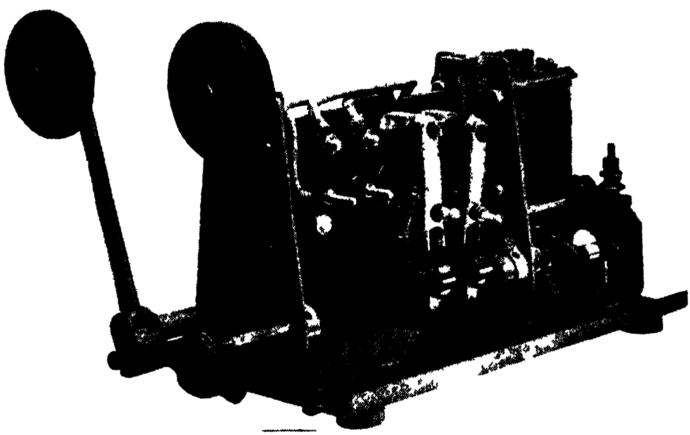


FIG. 197 LEVELLING WITHDRAWAL SWITCH
(*Dewhurst & Partner, Ltd*)

rollers are withdrawn so that they are clear of the levelling ramps. These ramps are fixed in the well at each floor so that the mid-position between the ramps at each floor corresponds to the rollers on the switch and to the correct levelling position. If the lift under normal operation comes to rest at a distance not exceeding about 11 in. either above or below the floor, one of the two levers will be operated, so causing the lift to move at slow speed in the required direction to floor level where the switch will be central between the two ramps.

THE "TRULEVEL" GEARED MACHINE. This machine has been patented by the Express Lift Co., and is used for car speeds up to a maximum of 200 ft. per min. Two views of the equipment are shown in Figs. 198 and 199 and it consists of a main driving motor coupled to the worm shaft of a worm reduction

gear, by a multi-vee rope drive, an auxiliary levelling motor mounted above the gear box and coupled to a friction clutch by a second multi-vee rope drive, an electro-mechanical brake, and the usual main driving sheave. The main motor is of the single-speed type of voltage to suit the supply characteristics and is mounted on a platform hinged to the bedplate. Means are provided for adjusting the positions of the two motors to

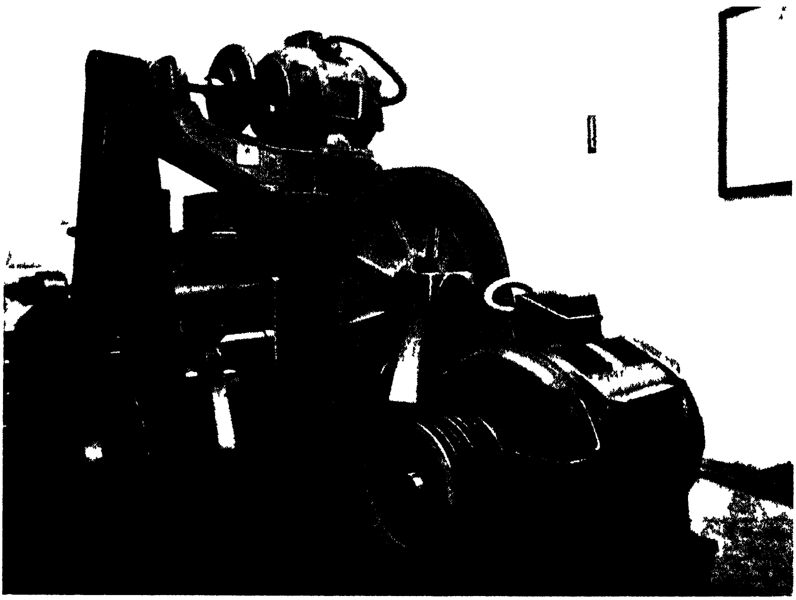


FIG. 198. "TRULEVEL" MACHINE
(*Express Lift Co. Ltd*)

take up initial stretch in the rope drives. The driving sheave and worm-wheel rims are both secured by fitting bolts to a spider thus eliminating keys, whilst the multi rope drives enable the motors to be more completely isolated from the rest of the machine than is possible with fixed couplings. One side of the single plate type friction clutch forms part of the brake drum and the other Ferodo-lined side forms part of the multi-vee rope pulley of the auxiliary levelling motor drive. Both the clutch and the brake are released by solenoid energized magnets

and engaged by springs, the magnets being operated by rectified direct current. A brake switch ensures prompt application of the brake shoes when the solenoid is de-energized and a

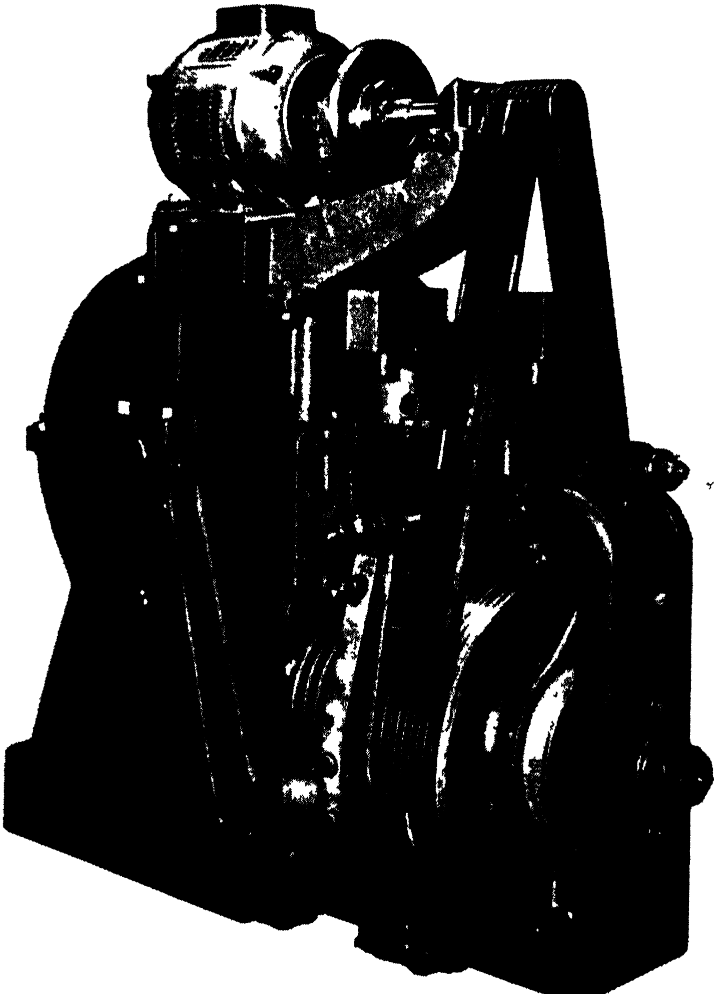


FIG. 199. "TRULEVEL" MACHINE
(*Express Lift Co. Ltd.*)

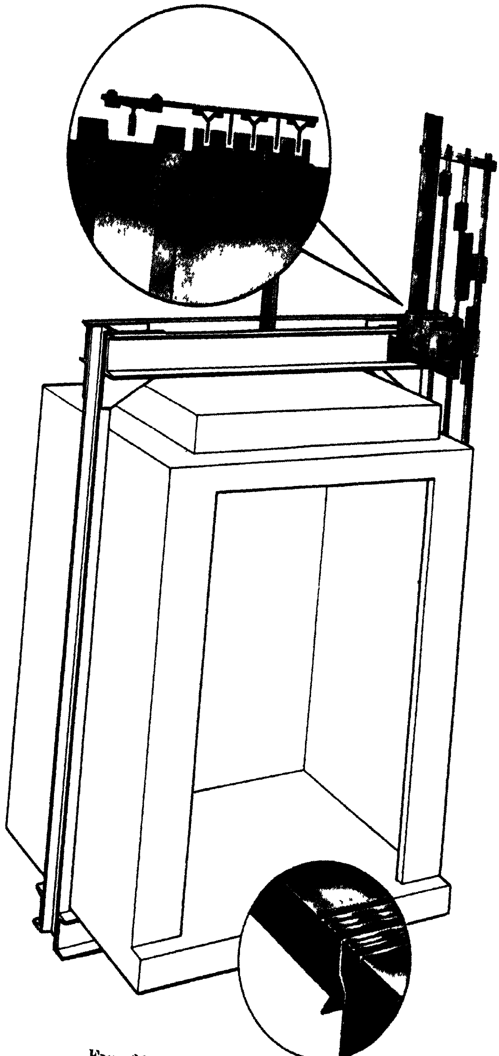


FIG. 200. INDUCTOR SWITCHES
(*Express Lift Co Ltd*)

clutch switch ensures that the main motor cannot be connected to the line until the clutch has been fully disengaged and also that the clutch cannot be engaged until the main motor has been disconnected from the line.

The main motor is used for accelerating and running the lift at full speed when the clutch is disengaged. The lift is slowed by the application of the brake, the main motor then being disconnected from the line. At the appropriate moment the single speed auxiliary motor is switched on, the clutch engaged,

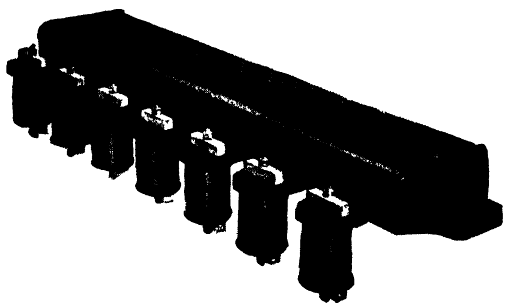


FIG. 201. INDUCER BOX
(*Express Lift Co. Ltd.*)

the brake relifted, and the car brought to the landing at the levelling speed, the motor being finally switched off and the brake applied when the landing is reached. The reduction in speed required for levelling is obtained by the rope drive with a maximum reduction of 6 : 1 and also by a difference in speeds of the main and auxiliary motors of up to 2 : 1. Hence the overall speed ratio may be as high as 12 : 1, giving a landing speed of about 16 ft. per min. with a maximum running speed of 200 ft. per min.

INDUCTOR AND INDUCER SYSTEMS. The signals required by the controller to initiate the slowing and stopping, i.e. the change over to auxiliary motor and the final brake application are provided by inductors or inducers mounted on the car. The Express Lift Co. also employ these means for effecting slowing and stopping on types of lifts other than their "Trulevel" lifts. For car speeds up to about 300 ft. per min. permanent magnet inductors have been used in the past, as many of these as

necessary being fitted on top of the car. Each inductor is constructed so that a gap exists, on one side of which is a flux generating device such as a permanent magnet and on the other side is a flux collecting pole. The flux so collected is used to actuate a small armature which operates current-carrying contacts wired to the controller switches. The inductors are operated by steel

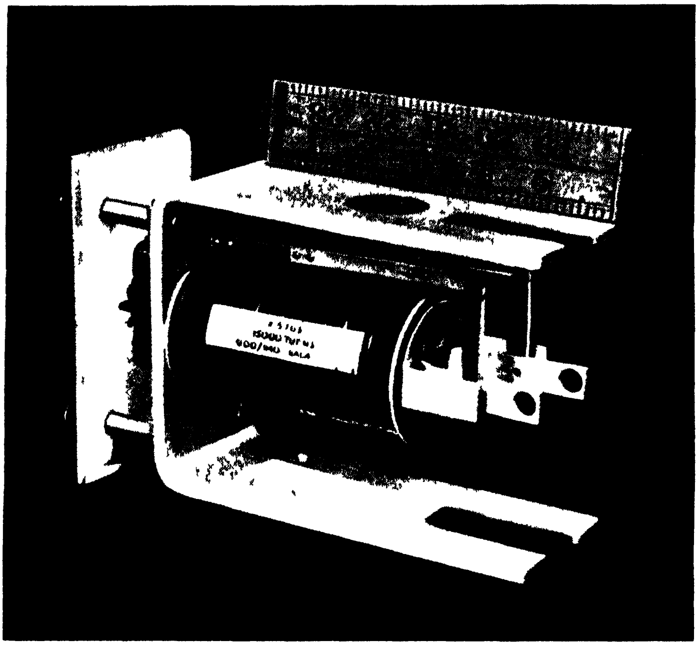


FIG. 202. SOLENOID INDUCTOR
(*Express Lift Co. Ltd*)

plates fixed in the well as shown in Fig. 200 and so situated that they pass through the inductor gaps at the correct moments for initiating deceleration and stopping. Hence when an iron plate passes through the gap the flux is diverted from the collecting pole and the armature becomes free to move under the influence of a spring, but as soon as the plate has left the gap the armature returns to its normal position. Usually three inductors per car and three associated rows of iron plates fixed in the well are provided, one for counting the zone

changes, and the others each for controlling up or down slowing or stopping.

The inductor system described above is unsuitable for high speed operation, however, and for speeds in excess of 300 ft. per min. the inducer is used. This consists of a pair of iron cored coils fixed to the car as shown in Fig. 201, a gap between the coils permitting of the entry of an iron plate so

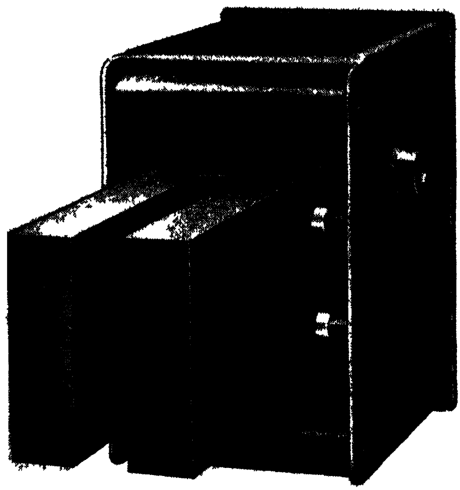


FIG 203. THE PLIOTRON UNIT
The operating coils are housed in the moulded projections
(B T-H)

that alternating flux generated by a.c. in one coil may be temporarily prevented from reaching the other pick-up coil. This latter coil is coupled to a valve amplifier so that only anode current flows to operate controller relays when a plate is in the gap which occurs when deceleration, stopping, or zone counting is required.

Whilst both the above systems have proved mainly satisfactory the former has a speed limitation and the latter, operating on the thermionic principle, is not quite as stable or flexible as would be preferred. Consequently a more reliable and robust inductor known as the solenoid inductor has been produced and this also permits a simpler control circuit. The

inductor is solenoid excited as against the previous permanent magnet type. This solenoid inductor, which is shown with case removed in Fig. 202, will replace the two earlier types on all post-war installations provided by this company and is suitable for use on lifts of all speeds.

The Pliotron unit, manufactured by the British Thomson-Houston Co., Ltd., is a proximity-type limit switch similar

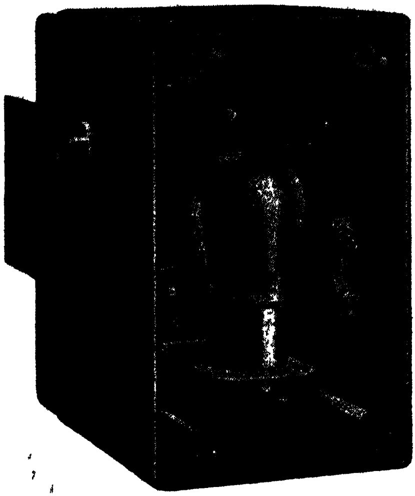


FIG. 204. REAR VIEW OF THE PLIOTRON UNIT
(Cover removed)
(B T-H.)

in principle to the inductor described above. The circuit includes two separate components, the unit illustrated in Figs. 203 and 204 and an electro-magnetic relay shown in Fig. 205. The unit consists of a sheet-steel case housing a triode valve and some of its associated circuit components. Two coils separated by an air gap are enclosed in moulded insulation projections on the front of the case. Normally the coils are magnetically coupled but can be decoupled by the interposition of a metal vane which does not touch any part of the Pliotron unit. This "proximity" effect serves to actuate the relay which is of simple construction, compact and quick-acting, and

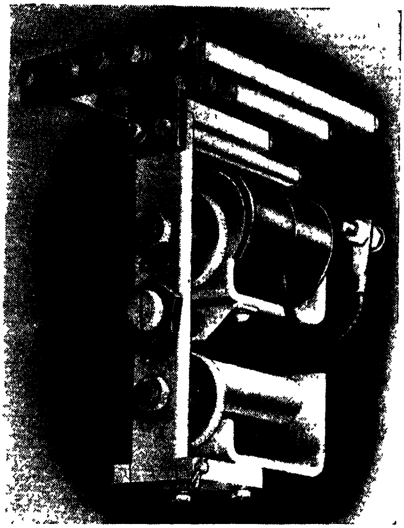


Fig. 205. Relay for Pliotron Unit
(*B.T.-H.*)

Fig. 206. Pliotron Units on Passenger Lift
(*B.T.-H.*)

fitted with silver contacts. The relay is mounted on the controller panel. The overall dimensions of the Pliotron unit are approximately $8\frac{1}{2}$ in. high, $5\frac{1}{2}$ in. wide, and $11\frac{1}{2}$ in. deep. The coils are normally magnetically coupled and the relay is then de-energized. Decoupling is effected by interposing a metal vane between them and this energizes the relay. The operation of the relay coincides for all practical purposes with the passage of the edge of the vane across the centre line of the two coils on the unit. Fig. 206 shows two pairs of units mounted on top of a lift car, one of the operating vanes being seen just above the unit. In some lifts it might be more convenient to mount the vane on the lift car and the unit in the well. Any number of units can be operated in succession by a single vane, or a number of vanes can successfully operate one unit.

# CHAPTER XIV

## CAR CONTROL SYSTEMS

A NUMBER of different methods of controlling the movement of the car from floor to floor are available, and the particular one selected depends upon the service required, the type of building, and the car speed. The various methods may be grouped, broadly, into two systems as follows—

(*a*) Those requiring an attendant.

(*b*) Those in which the car is completely under the control of passengers in the car or persons on the landings.

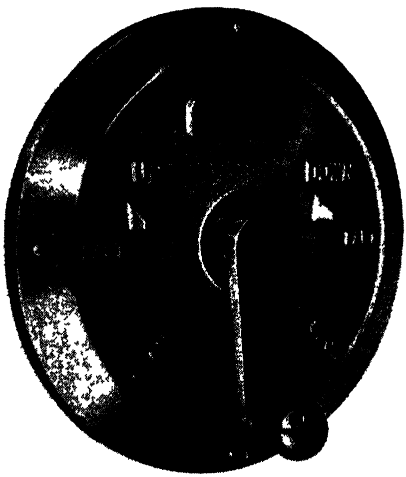


FIG. 207. TWO-SPEED CAR SWITCH
(*Dewhurst & Partner, Ltd.*)

In group (*a*) we have systems of control known as *car switch*, *departmental stores*, and *signal*, whilst under (*b*) come *automatic*, *semi-automatic*, and *automatic collective*. *Dual control* may be used with or without an attendant.

**Car Switch Control.** This requires a single call button at each landing, pressure on which registers a call on an indicator board fitted in the car, thus making the attendant aware of the floor at which service is required. Movement of the car switch by the attendant to the UP or DOWN position starts the car in the required direction, stopping being performed by returning the switch to the OFF position as the car approaches the desired floor. Good floor levelling is dependent upon the judgment of the attendant in returning the switch to the OFF position when the car is at the correct distance from the required floor. The car switch automatically returns to the OFF position under the

action of a spring and locks itself there when released. For car speeds up to about 100 ft. per min. a single-speed motor is used, and for speeds up to 200 ft. per min. a two-speed motor is necessary so that levelling can be done at the slower speed. In the latter case the car switch has a fast position and a slow position for each direction of travel. A typical car switch for a two-speed lift is shown in Fig. 207. Although this manual stopping of the car was used extensively in past years, it is now mainly employed for passenger lifts serving a small number of floors and where traffic is light, or for goods lifts. A gate is essential as a door would not allow the attendant to judge the position in the well for operating the switch for slowing and stopping. The attendant resets the indicator after calls have been answered.

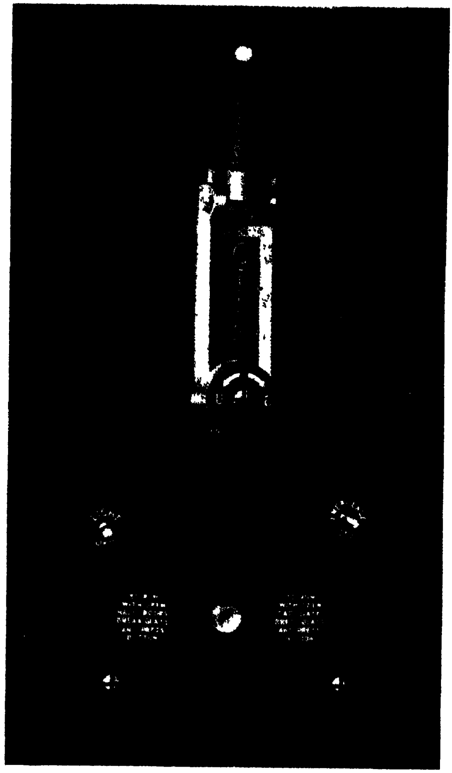


FIG. 208. CAR SWITCH
(*Waygood-Otis, Ltd.*)

An improvement on the above control is available if the lift is fitted with a self-levelling device. In this case the attendant merely releases the car switch so that the car stops somewhere within the levelling zone, and the self-levelling equipment then automatically stops the car at the landing.

A further improvement is the provision of automatic stopping in which the attendant releases the switch after passing a floor and the car automatically slows and stops at the next floor, provided that the switch has been released soon enough for the

automatic slowing and stopping equipment to function. A car switch for automatic stopping is shown in Fig. 208, which incorporates a light switch, emergency stop, and a glass-enclosed emergency button which permits the car being moved with the doors open. For passenger lifts provided with car switch control, automatic stopping, car position indicator in the car, and power-operated doors, the doors are closed by the car switch and opened automatically as the car stops.

**Departmental Store Control.** This is the name given to a system which has been developed for use in departmental stores where the lift normally stops at each floor and the attendant is relieved of any effort to make accurate landings. Buttons are not required for this control, but the landings have illuminated car position and direction indicators. When the car switch is moved to the START position, the power operated car and landing doors close automatically, and the car commences to accelerate. The centring of the car switch causes the car to stop level with the next floor, and both car and landing doors open automatically. If it is desired to pass floors, the car switch is held in the start position.

**Signal Control.** This is used on banks of high-speed lifts, such as are installed in large offices and hotels, employing variable voltage gearless drives, automatic levelling, and power operated doors, and travelling at speeds up to about 600 ft. per min. in this country, and 1 400 ft. per min. in America. A person at a landing requiring a car, presses either the UP or DOWN button, depending upon the direction in which he wishes to proceed, and the first car travelling in the desired direction and that can accommodate him stops at the landing. As the car approaches the landing at slow speed (under the control of the automatic levelling gear) the landing light is illuminated, either UP or DOWN, depending upon the direction of travel, thus indicating that the car will stop at that floor. On reaching the landing the car levels automatically, the doors open, and the waiting person enters and calls the number of the floor to which he wishes to proceed. The operator then presses the corresponding car button and moves the car switch to the start position, after which the doors automatically close. The car accelerates and stops automatically at the next floor where a car or landing call has been registered. Car or landing

buttons may be pressed in any order, and whether the car is stationary or in motion. A non-stop button in the car enables the attendant to pass any landing if the car is full; the stopping of the first available car resets the control so that unnecessary stops are not made by other cars. A special emergency control

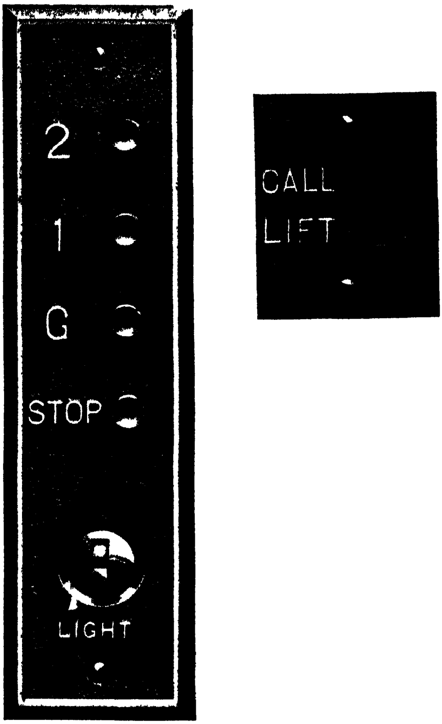



FIG. 209. OPERATING BUTTONS
(*Wm Wadsworth & Sons*)

lever in the car provides for travel at the slow levelling speed for inspection and maintenance purposes.

**Automatic Control.** With this type, a single call button is fitted at each landing (Fig. 209) and a set of buttons in the car. The car buttons comprise one for each floor and an emergency stop button, as shown in Fig. 209. Fig. 210 shows a landing call button with a "lift coming" signal. A passenger,

after entering the car and closing the gates, presses the car button corresponding to the desired floor, and the car then starts and automatically stops when the floor is reached. Any other calls which may be made from a landing when the car is in motion are ignored. Whilst the car's ultimate destination is controlled by the passenger, the accuracy of levelling is dependent upon the setting of the slowing and stopping switches and adjustment of the brake, unless automatic levelling gear is installed. This control is used when the traffic is occasional and not sufficiently heavy to justify the employment of an attendant. Except in special circumstances this control should not be used for lifts of capacity more than about ten persons as it is not economical to have a large lift answering single calls. A button system consisting of a full set of landing buttons (one for each floor) as well as a full set of car buttons, is sometimes employed. This is useful when the lift is used for both passenger and goods traffic and it is desired to send the lift to any floor without a passenger.

FIG. 210. CALL PUSH AND SIGNAL
(*Express Lift Co Ltd*)

**Semi-automatic Control.** UP, DOWN, and STOP buttons are fitted in the car and at each intermediate landing, as in Fig. 211, whilst UP and STOP buttons are provided at the top terminal landing, and DOWN and STOP buttons at the bottom terminal landing. The momentary pressure of a button, either in the car or on a landing, causes the car to move in the direction indicated, whilst pressure on a stop button stops the car. A modification of this scheme consists of UP and DOWN buttons at each landing (Fig. 211)

and in the car, the car only travelling when the button is actually depressed, and stopping on the release of the button. This results in more accurate floor stopping than with Up, Down, and Stop buttons. These systems are sometimes employed in preference to the fully automatic system for slow-speed goods lifts which are not provided with corrective levelling, so as to secure more accurate levelling under varying conditions of load.

The semi-automatic control, however, is now mainly employed on lifts serving two floors only. In this case Up, Down,

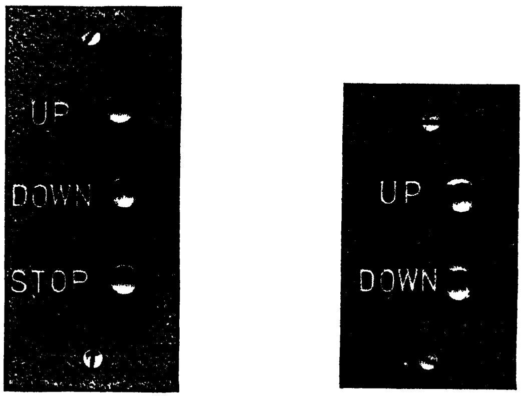



Fig. 211. Call Buttons
(*Wm. Wadsworth & Sons*)

and Stop buttons are fitted only on the landings, when the lift is used solely for goods traffic, but Up, Down, and Stop buttons are also required in the car if passengers are to be carried. When two floors only are served, the stop button is for emergency purposes alone, as the lift stops automatically on reaching the floor.

**Automatic Collective Control.** This system has been developed during recent years with the object of providing a fully automatic push button system giving superior service to that obtainable with the ordinary automatic system. The main disadvantage of the automatic control is that it is possible for passengers waiting at a landing to see the car pass, and travelling in the direction in which they wish to proceed, without

them being able to gain admittance. This, however, is not possible when collective control is installed, provided the landing button is pressed sufficiently in advance of the arrival of the car.

UP and DOWN buttons are fitted at each intermediate landing, single buttons at the terminal landings (Fig. 212) and a full set of buttons, together with an emergency stop button, in the car (Fig. 213). Every button pressed, whether the car is stationary or in motion, registers a call. Up and down calls are answered during the up and down journeys respectively, in the order in which the floors are reached. If the car is at, say, the ground floor and one or more persons enter the car, close the landing and car doors, and press the appropriate car buttons, the car will start, and stop at the floor corresponding to the lowest numbered car button which has been pressed. The order in which the buttons are pressed has no bearing on the sequence in which the car will stop at the various floors, providing that the button for a given floor is pressed sufficiently in advance of the arrival of the car at that floor to enable the stop to be made. The car, while travelling in the up direction, will also stop in the same manner in response to all up landing button calls. The upward direction is continued until the uppermost call has been answered. If a down call is registered at a floor above the highest up stop, the car will continue in the up direction to the floor at which a down call is registered. It will then reverse automatically, even though not at the top

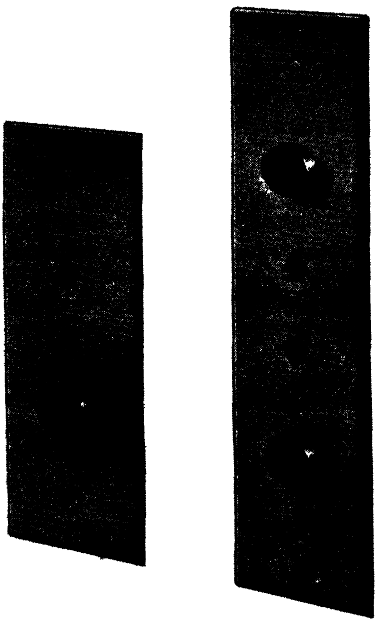


FIG. 212. "TELL-TALE" PUSH BUTTONS
(*Waygood-Otis, Ltd.*)

terminal floor, provided car buttons for floors above this point have not been pressed, and will start down, stopping in response to all down calls registered at lower floors in advance of the arrival of the car at these floors. The car will continue in the down direction until the last floor is reached for which a car or down landing button has been pressed. If, after all down calls are answered, the car is not at the bottom landing, it will continue down in response to the pressing of an up button at a floor below the last stop. If, however, no button is pressed below this floor the car will reverse automatically, and start up in response to the pressing of either up or down buttons above this floor. In other words, the car will travel in either direction until the last floor has been reached at which an up or down button has been pressed, or for which a car button has been pressed. It is not necessary that the car make complete round trips.

If traffic is intermittent and only one call is registered at any one time, the lift will operate in the same manner as a single automatic push button lift, but will become collective automatically when more than one call is registered at one time.

Precedence is given to the passenger in the car in the following manner. If, after the car has started to slow down at a given floor in response to the pressing of a button at that floor (this call being the last call registered in the direction in which the car is going) another call is registered at a floor beyond the one at which the car is in process of stopping, the stop will be completed. After the passenger has entered the car he may dispatch the car in accordance with his wishes, provided he presses the proper car button before closing

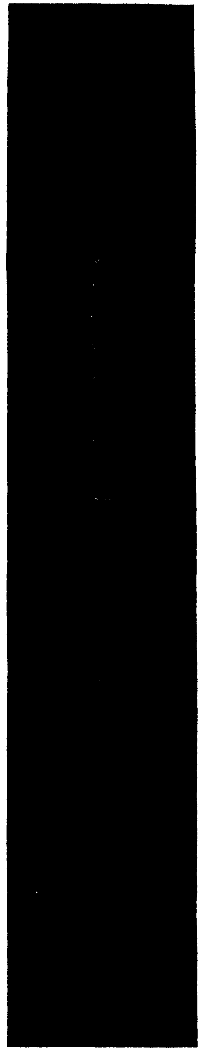


FIG. 213. CAR CONTROL STATION (*Express Lift Co. Ltd.*)

the car gate or within about five seconds after the car gate has closed. He is, therefore, spared the inconvenience of being taken in the direction opposite to that which he expected to go. For example, if the car is at the first floor and down buttons are pressed at the third, fifth, and seventh floors, the car will travel to the seventh floor. If, after the car has commenced to stop at the seventh floor, an up or down button is pressed at the ninth floor, the stop at the seventh floor will be completed and the call at the ninth floor will not be answered until after the car has reversed at the seventh floor and completed its downward trip in response to the car buttons pressed by the passengers who entered the car at the seventh, fifth, and third floors. If the ninth floor button had been pressed before the car commenced to stop at the seventh floor, the car would have proceeded to the ninth floor before answering the down calls at the lower floors. The same operation is effective in both directions. If, after the car has stopped at a given floor in response to the pressing of either a car or landing button, the car or landing door is not opened within about five seconds, the car will respond to any other calls which may be registered, or if no calls are registered, the car will return to the home landing.

Arrangements may be made to enable the car to park automatically at any preselected floor, after all calls have been answered, this facility being particularly desirable when important persons are located on a certain floor or when heavy traffic is expected from a particular floor at certain periods of the day. For instance, the service may be greatly improved in a block of offices if, during heavy morning traffic, the car is made to return automatically to the ground floor or to park at, say, the sixth floor in the evening, to give prompt service in the downward direction instead of remaining at the floor to which it was last called.

The above form of control, which is sometimes referred to as *directional collective*, may be modified to enable calls to be answered in the same sequence in which the buttons are pressed. This is known as *interceptive collective* control.

The system may be still further modified to work as an automatic push button control in the up direction and as directional collective in the down direction only. This *down collective*

control is sometimes employed in flats and is based on the assumption that, whilst tenants and their visitors travelling upwards usually wish to travel directly to their own floor, all persons travelling downwards wish to alight at the ground floor. Hence, an upward travelling passenger is enabled to travel directly to his own floor without interference, whilst in the downward direction there is no reasonable objection to the lift stopping at intermediate floors to pick up other passengers who almost certainly also wish to travel downwards to the ground floor.

The lift normally stands idle with the doors closed, from which position it moves in either direction in response to landing calls or will respond to the landing call for the floor at which the lift stands, thus opening the doors. If the lift car moves upwards in response to a call, all such calls are registered, and the lift proceeds to the highest call, such calls which are passed during this journey to the highest call being retained for service during the next downward journey. On stopping for the highest call, the doors open, and the landing pushes are disconnected to prevent higher calls being registered. Any calls registered during the upward journey are stored and held inoperative until the doors have opened and then reclosed. This gives car preference, and a passenger may enter the car and select a direction of travel without interference from further landing calls or calls already registered. If the passenger operates a car push for an upward direction before the doors close, the landing pushes will be disconnected, and any registered calls will be held inoperative during this journey. Where the car pushes are operated for more than one floor in the upwards direction, the lift will proceed to the highest floor, retaining the others for attention during the next downward journey. When the car starts downwards, both car and landing pushes are operative to give service below the lift car, and the car stops automatically and in sequence in response to such calls made during the downward journey. On the downward journey it is impossible for the direction to be reversed by car or landing pushes until all down calls have been answered.

**Duplex Control.** This is used when two lifts are installed in adjacent wells. A common landing button serves for both lifts, and a passenger wishing to make a call momentarily

presses the button. A "Call Accepted" signal is immediately illuminated, and when a car answers the call a "Lift Coming" signal is illuminated. With power-operated doors, pressure on a car button automatically closes the doors, and then the lift starts. Landing calls are registered and are allocated one at a time as the cars become free from car calls.

**Triplex Collective Control.** Triplex Collective Control is for three adjacent collective control lifts with a common landing call button system, and the nearest car travelling in the required direction answers the call.

**Dual Control.** This is a combination of car switch control and one of the automatic forms of control, and requires a car switch and indicator and a full set of call buttons in the car as shown in Fig. 154. The lift may be worked either by an attendant operating the car switch or by the passengers operating the buttons, depending upon the position of a transfer switch. For light traffic the lift is operated by passengers, but during periods of peak load, by an attendant, with a consequent improvement in the service.

A full dual system of control may also be provided without the use of a car switch. In this case the operation of a transfer switch in a locked box on the landing converts the lift from automatic to a service equivalent to car switch, but by still using only the car buttons. Pressure on a landing button illuminates the corresponding floor button in the car and sounds a buzzer. The call is cancelled only when it is answered. The attendant can cause the car to stop at intermediate floors in response to landing calls by pressing the appropriate floor button while the car is in motion. Thus, while the lift is travelling to the fifth floor, a call from the third floor can be answered by pressing the third-floor button, provided the car has not already entered the third-floor stopping zone.

**Dual Collective Control.** This is a collective control with the additional facility of being operated by an attendant during very busy periods or on special occasions. The closing of the doors and the starting of the lift are controlled by the attendant's special UP and DOWN buttons in the car. For starting, the calls are dealt with automatically and in order as in collective control, but the attendant may by-pass calls if the car is full. This is done by either a by-pass push or an automatic

micro-switch operated by full load on the car floor. The operation of a small change-over switch converts the lift to collective control when the attendant leaves the car. Automatic parking of the car, usually at the ground floor, is frequently provided, so that between calls the car is waiting at the floor where service is most likely to be required.

A variation of this control comprises down collective operation when under passenger control and interceptive collective when operated by an attendant.

**Signal Collective Control.** This combines the features of signal and collective controls, and therefore may be used with or without an attendant. It can also be used with one, two, or three cars and is intended to be used normally as signal control and only occasionally, e.g. at night, by passengers. Passengers wishing to call a car momentarily press an UP or DOWN button on the landing, and the button is illuminated until the call is answered. When on attendant control, the attendant uses a continuous press start button to close the doors, and after these are locked the car starts automatically. Without attendant, the car starts after the passenger has pressed the appropriate floor button and the doors have closed. Once started, the car answers the nearest call from the car or landing in the direction in which it is travelling. All other calls are answered strictly in rotation. When the car reaches the highest floor, its direction is automatically reversed. For three-car banks, hall lanterns are fitted over each entrance, and direction arrows are also fitted to the car control panel.

With a two- or three-car bank the landing call system is common to all lifts, and each call is automatically allocated to the best-placed car. At the parking floor a START signal and a gong denote the correct time of leaving that floor for each lift. The START signal is received according to the registered calls in the system and the position of the other cars. These signals are controlled so that the cars are effectively spaced and so give the best possible service. When operated by passengers, a car at a parking floor always responds to a car call.

A starter panel is mounted outside the lifts, and this houses the car light switches, transfer from signal to automatic collective control switches, motor generator switches, and door pushes for parking the cars out of service during slack periods.

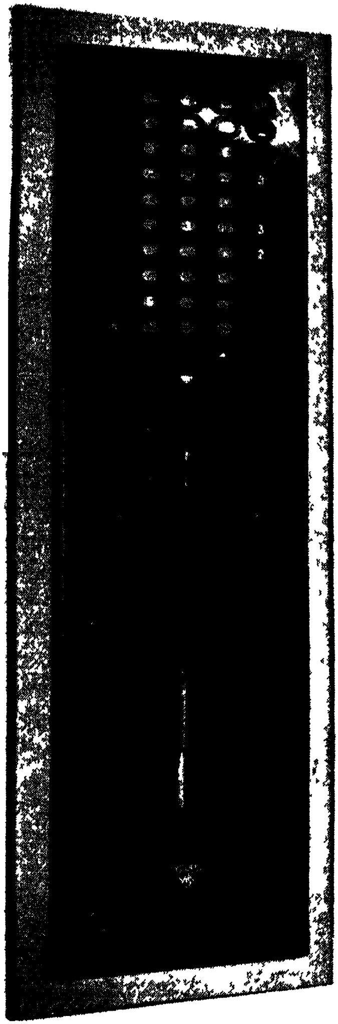


FIG. 213A. COMBINED INDICATOR AND SERVICE CONTROL PANEL FOR A BANK OF THREE LIFTS USING MULTIPLE CALL CONTROL FOR THREE CARS
(*Express Lift Co. Ltd.*)

The car control panel contains in addition to the floor buttons a combined stop and alarm switch and, for attendant use, reversing buttons and a PASS button. A DOOR OPEN button is also fitted.

When operated by passengers the cars are subject to an overriding control which puts them out of service or restores them to use separately as the traffic falls off or increases. A combined indicator and service control panel for a bank of three lifts using signal collective control is shown in Fig. 213A. The top panel indicates the movements of all the cars and the location of landing calls. The lower panel can be opened by the supervisor so that he can make the necessary adjustments to the service of the lifts.

**Modern Practice.** Car switch was one of the earliest forms of control and had the advantage of requiring a simple controller and also of giving an attendant full control over the starting, stopping and levelling. A good attendant could undoubtedly provide an excellent service which, by carefully watching the indicator and observing the position of passengers, was some measure of collective control. The advent of automatic control enabled a service by passengers themselves when the duty

was light and it was uneconomical to employ an attendant. These two controls, together with the combination of the two (dual control), were in general use for many years. However, as the size of buildings and the intensity of lift traffic increased, the shortcomings of both controls became apparent. Automatic control gave a service to an individual passenger or to one group at a particular landing, and there was no means for service to be given to passengers at intermediate floors even if they too wished to travel to the same floor. The need for an improved automatic service resulted in the introduction of collective control, which has now practically entirely replaced the original automatic control for passenger service, even in the smaller and less busy offices. The difficulties experienced with car switch control were the considerable variations in the service if the attendants were not efficient. In recent years it has become difficult to recruit and retain good attendants, and the wages aspect has further resulted in a considerable falling off in popularity of car switch control, even with such features as automatic levelling and power doors. There has been, too, a corresponding increase in the facilities available, notably the feature of interconnecting a bank of lifts, and in the reliability of automatic forms of control. As a result, experience tends to show to-day that it is unlikely that a team of efficient lift attendants can, throughout a day, give such a good service as would be provided by a corresponding bank of modern interconnected collective control lifts. These problems have already been encountered in America where in many large buildings of up to thirty storeys the lifts are operating successfully without attendants. Even in this country where lifts have been changed over from car switch to automatic collective control, there has been an improvement in the service. There are, therefore, clear indications that control without attendants may, in the near future, replace control with attendants even in the large densely-populated office buildings, particularly if there is some advancement in the technique of enabling lifts to adapt themselves automatically to varying traffic conditions.

# CHAPTER XV

## CONTROLLERS

**General.** The controller is usually located in the motor room, but care should be exercised in choosing its exact position in order to ensure that sufficient clearance exists between the controller and any walls, and, further, that there is no possibility of a maintenance engineer, when working on the controller, coming into contact with a moving part of the lift. The various contactors, relays, auxiliary resistances and fuses are mounted on a panel of slate, " Sindanyo," or other insulating material, the panel in turn being fixed to an angle iron framework. The control relays and the starting, accelerating, and retarding contactors, together with their associated interlocks, are electromagnetically operated, the magnet coils being supplied from the control voltage. Contacts performing certain operations require delayed actions of varying durations, and this is effected by dashpots, mechanical time lags, condenser and resistance networks, or a thermionic valve and condenser circuit. Copper-to-carbon and copper-to-copper are the contact combinations generally adopted. Blow-out coils are fitted where necessary to the contactors in order to extinguish the arc, and when copper-to-copper contacts are used these must be carefully designed to give a "rolling" contact. By this means the portions of the contact surfaces on which the circuit is made and broken, and which suffer any deterioration due to arcing, are slightly removed from the portions which actually carry the current. If the contacts are not correctly designed and the roll is insufficient, or is lost due to faulty maintenance, there is danger that the arcing will cause the contacts to weld, and if the reversing contactors are so affected serious damage may result. Copper contacts are sometimes faced with silver of a thickness up to about 0·05 in. to minimize deterioration due to arcing. The main reversing contactors carry a current depending upon the size of the motor and at the voltage of the motor supply, whilst the operating coils of the contactors, relays, and brake carry comparatively

small currents, the voltage being either that of the mains (a.c. or d.c.) or a separately produced control voltage. D.c. magnets are more silent and generally more reliable than a.c. magnets and it is, therefore, frequently the practice to supply all control circuits and the brake coil from a direct voltage which, in the

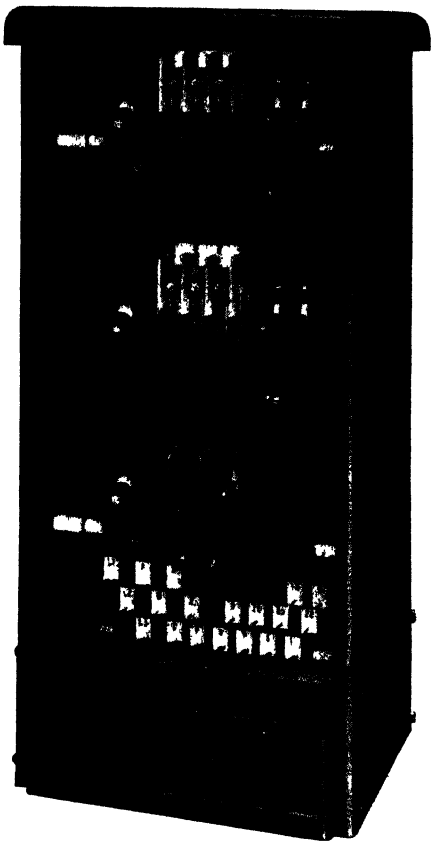


FIG. 214. CONTROLLER FOR SINGLE-SPEED LIFT
(*Wm. Wadsworth & Sons*)

case of a.c.mains, is obtained from a double-wave rectifier. The control voltage employed is generally between 100 and 200 volts. A typical controller for a single-speed lift is shown in Fig. 214, a controller for a two-speed tandem motor lift in

Fig. 215 and a controller for two interconnected collective control lifts in Fig. 216.

**Low Voltage Controller.** The type of controller employed by

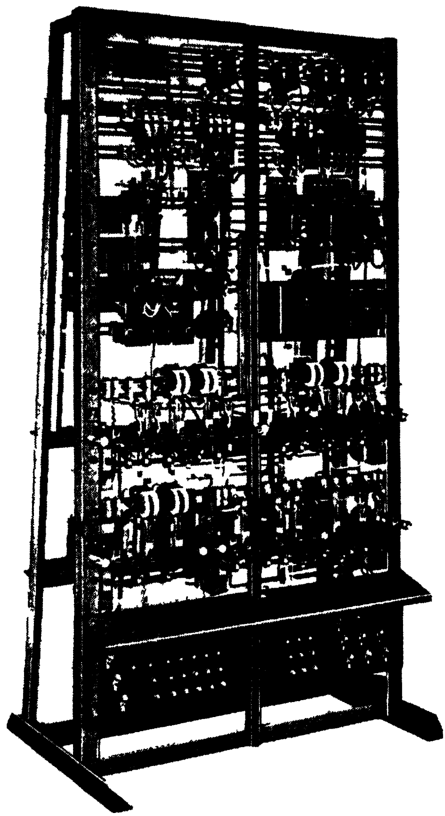


FIG. 215. TWO-SPEED CONTROLLER
(*Etchells, Congdon & Muir*)

the Express Lift Co. differs in many respects from those used by other British firms and a brief description is therefore warranted. Two views of a typical controller are shown in Figs. 221 and 222. The controller voltage employed has in the past been 50 volts—unusually low for a lift control voltage—

which is the standard Post Office telephone exchange voltage. For post-war work however, the lift control voltage has been raised to 100—still low—to reduce troubles due to voltage drop whilst retaining the advantage of a relatively low voltage for insulation purposes. The telephone type equipment which was

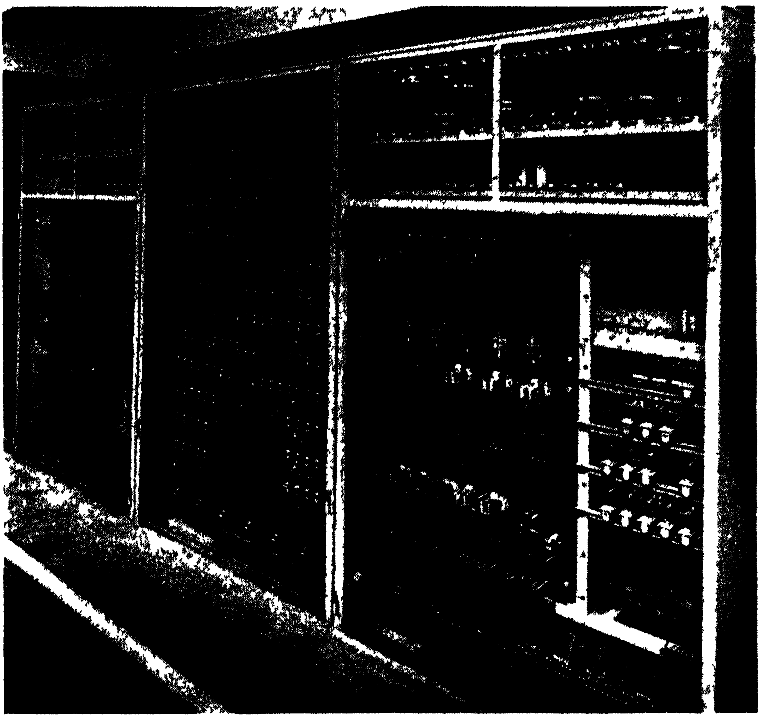


FIG. 216. CONTROLLER FOR TWO INTERCONNECTED COLLECTIVE CONTROL LIFTS
(*Express Lift Co Ltd*)

used has now been replaced by a heavier type designed to meet the requirements of lift service. The type of relay used is shown in Fig. 217 and is more robust than a telephone relay.

The contact assembly is built on two separate pile-ups of nickel-silver contact springs fitted with silver contacts. Each pile-up is clamped by two screws and is fixed to the yoke by a third screw. The stationary contact springs are tensioned

against the moulded buffer block mounted on the armature end of the yoke. The armature is pivoted on a pin located in an adjustable saddle fixed to the yoke. The adjustment of this saddle enables the armature to be correctly positioned to give the required operating stroke. This relay may comprise between two and six contacts in any combination of make and break or, alternatively, two or four change-over contacts. The

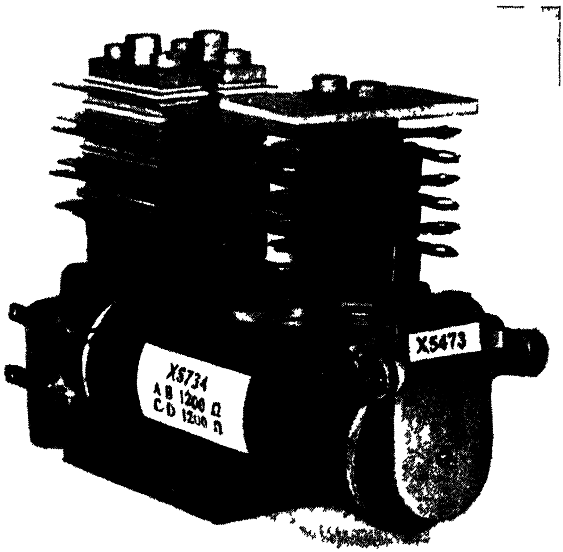



FIG 217. CONTROLLER RELAY
(*Express Lift Co Ltd*)

operating time is between 30 and 50 milli-seconds and the release time between 10 and 30 milli-seconds. The maximum rating of the contacts is 5 amps, but for long life of the order of ten million operations on non-inductive loads the rating is 2 amps at 50 volts, 0·7 amp. at 100 volts or 0·2 amp. at 200 volts d.c., and approximately double these current figures on corresponding a.c. voltages. For inductive loads, spark-quench circuits are provided to obtain reasonable contact lives. The operation of the relay may be delayed by the use of resistances and condensers or thermionic valve and condenser circuits.

The selector for this controller has been described in Chapter XIII.

Three standard sizes of main contactors for operating from 100 volts are available for 15 h.p., 25 h.p., and 40 h.p. The

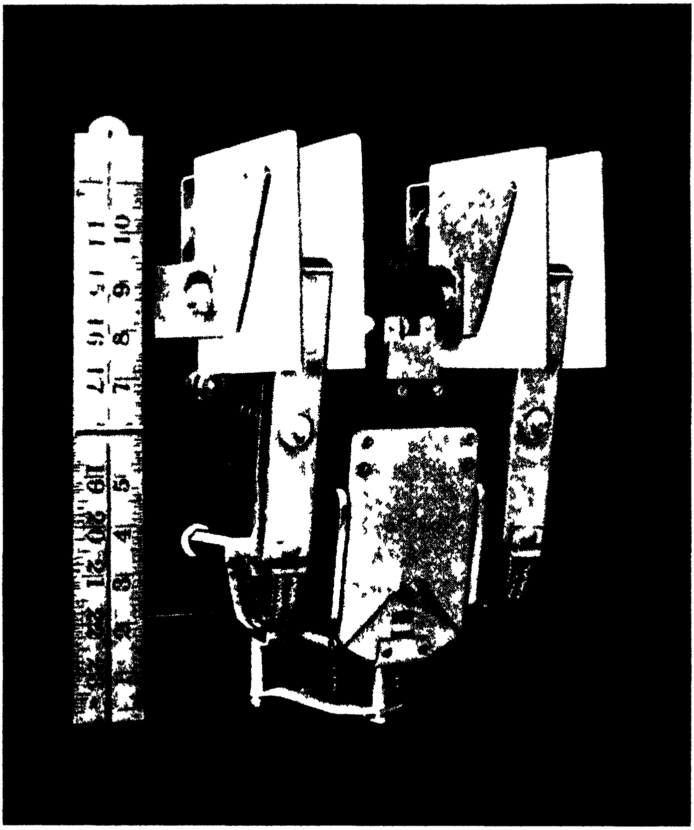


FIG 218. A CONTROLLER MAIN CONTACTOR
(*Express Lift Co Ltd*)

main contacts are copper to carbon to eliminate as far as practicable the possibility and the consequences of contacts welding together. Auxiliary contacts for these contactors are similar to the relay contacts, i.e. nickel silver springs with silver contacts. The armatures are pivoted on the knife edge principle.

A 25 h.p. contactor is shown in Fig. 218. Starting contactors which have a heavy duty to perform are similar to the main contactors, but have heavy silver to silver contacts instead of copper to carbon.

**Control Features.** One of the most important functions of a controller is to ensure that it is impossible for the lift to be operated when any landing or car gate is open. This is usually effected by wiring the gate interlocks in series in one of the mains to the control circuits (see Chapter X).

With automatic lifts it should not be possible to interfere with the car's motion by operating a landing button when a passenger has entered or is travelling in the car unless collective control is used. With this type of control it is possible to stop the lift car at any intermediate landing for the reception or discharge of passengers. A delayed contact associated with the car gate contact is arranged to cut out the landing buttons for about five seconds after the passenger has entered the car and closed the gates. He is thus allowed this period in which to select and operate the required car button (see Chapter X). If the car button is not pressed during this interval, the car may be called to any floor by the operation of the relative landing button. Immediately a car button is pressed, however, the controller is arranged to cut out the landing buttons until the car has reached the end of its journey and the passenger has left the car and closed the gates. This is effected by incorporating a relay which is energized by the pressing of a car button, the relay contacts cutting out and reinserting the landing buttons at the commencement and end of each journey respectively.

To guard against the possibility of the car or counterweight encountering an obstruction, a relay is connected in the mains and is energized when a reversing contactor operates. After a period of from 1½ to 2 complete journeys, a lagged contact (one with delayed operation) of this relay is arranged to cut off the control supply. This contact is usually of the hand reset type, and therefore the cause of the trouble may be removed before resetting the contact. As a precaution against the main contactors welding it is sometimes the practice to arrange that this delayed contact disconnects the no-volt coil on the main circuit-breaker, and thereby cuts off both the motor and control circuits. Another method of providing this safeguard is by

arranging that a condenser discharges through a neon tube or a resistance network if the controller remains energized longer than required. The discharge current operates a relay which cuts off the control supply.

A reverse-phase relay should be incorporated in the controller of a polyphase motor, the functions of this relay being to guard against damage to the motor due to low voltage, phase reversal, and phase failure. The relay operates on the induction motor principle, a disc acting as the rotor. The relay contact is opened and closed by the motion of the disc and is kept closed by the operating coils when the phases are in proper relation. When reversal occurs, the rotor turns in the opposite direction, thereby opening the relay contacts which in turn cut off the motor supply and prevent operation of the motor in the wrong direction. Low voltage reduces the relay torque and the contacts again open, thus cutting off the motor supply and preventing possible stalling, burn-out, and increased speed. When phase reversal occurs, the relay loses its torque and the contacts open and thus guard against a possible motor burn-out due to running on single phase.

It is frequently the practice to interlock the motor and control circuits so that, in the event of a failure of the motor supply, the control supply is automatically disconnected. This is achieved with a polyphase motor supply and a single-phase control supply by inserting two relays in the mains, these relays being supplied from different pairs of line wires. A contact of each relay is joined in series in the control supply so that in the event of any phase becoming disconnected the controller is cut off. With a rectifier d.c. control supply the two circuits may be interlocked by means of two opposed relay coils; one supplied from the d.c. control voltage, the other from a separately rectified d.c. voltage obtained from the polyphase motor supply. When both coils of the relay are energized, the contact closes and completes the control circuit. If either the motor supply or the control supply fails, one of the coils is disconnected and the relay contact thereby opened.

All controller wiring should be of the flame-resisting type.

The operating handle of every car switch lift should be arranged to return to the OFF position when released.

To safeguard the motor against possible damage caused by

the operation of the reversing contactor before the motor has come to rest, a lagged contact is wired in the control supply to the reversing contactor coils. This contact closes a few seconds after the reversing contactor opens at the end of a journey, thus giving the motor time to come to rest before the contactor can be re-energized.

In addition to the reversing contactors being electrically interlocked, i.e. an auxiliary contact of each contactor being joined in series with the operating coil of the other, they are also mechanically interlocked as an additional safeguard against both operating together.

Other electrical interlocks have for their objects the prevention of the fast- and slow-speed contactors operating together, and ensuring that any accelerating and decelerating rheostats are inserted in correct sequence. The control circuit is sometimes interlocked with the brake hand release so that the controller is disconnected when the brake release is operated. It is thus impossible for the lift to be operated if the hand release has been overlooked after operation during testing. When the car safety gear operates, the motor is overloaded, and to prevent the possibility of damage if the fuses fail to blow, an interlock switch is frequently fitted to the gear so that when the safety gear sets, the switch cuts off the control circuit. In addition, this switch prevents the car from moving if the proper clearance does not exist and the safety jaws scrape the guides.

A further facility invariably provided on lift controllers consists of a change-over switch, the operation of which, together with the pressing of associated test buttons, permits of the lift being worked from the motor room for test purposes.

It is now recognized that accurate lift working records are an essential to efficient maintenance and service, and therefore energy meters to record the lift's electrical consumption, and counters to record the number of operations of the controller, are now being fitted as standard items of the control equipment. Operation counters are usually of the "Veeder" pattern and generally register the number of operations of the reversing or accelerating contactor. More complete data are obtained by fitting, in addition to an operation counter, a revolution counter on the main driving shaft and thus obtaining a record of the distance travelled by the car during any period.

## CAR SWITCH CONTROLLERS

With this type of controller, floor selection and stopping are usually controlled entirely by the movement of the car switch, although with many modern high-speed controllers the stopping is performed automatically and independently of the car switch. In the latter types the car switch only performs the functions of starting and of selecting the floors at which stops are to be made, the switch being returned to the OFF position after passing the floor immediately preceding that at which a stop is required. With ordinary single- or two-speed controllers for speeds up to about 120 ft. per min. and 300 ft. per min. respectively, starting and accelerating are performed by moving the car switch in the appropriate direction to the first position. If two speeds are employed, the switch is then moved to the second position, after which the motor accelerates to its full speed. On approaching the desired floor, the switch is returned to the first position and the motor decelerates to its lower speed. Finally, the switch is returned to the OFF position and the car is brought to rest, the accuracy of the levelling depending upon the operator's judgment in returning the car switch at the correct moment.

**Elementary Car Switch Controller.** The fundamental operations of a two-speed controller will be understood by referring to the diagram shown in Fig. 219. In this, as in subsequent controller diagrams, the detached contact method of drawing the diagrams has been adopted, in which the contacts of an electromagnet bear the same letter as that given to the magnet operating coil; thus $C1$ and $C2$ are contacts of an electromagnet whose operating coil is labelled $C$. All contacts are shown in their normal positions, i.e. with the lift at rest. From the diagram it will be seen that there are five positions for the car switch, a slow position and a fast position for each direction of travel, and a centre off position. When the car switch is moved to the up direction, first position, a circuit is made for coil $A$ of the main UP contactor via +ve main, car switch, $A$, UP stopping terminal limit, and –ve main. The reversing contactor (not shown), operated by $A$, closes and connects the supply so that the motor is ready for operation in the UP direction. Contact $A1$ closes and a circuit for the slow-speed coil $S$ is made via +ve, $C1$, $S$, $A1$, and –ve. The contactor

operated by $S$ (not shown) now closes and joins the main supply through to the slow-speed winding of the motor from the reversing contactor of $A$. Interlock $S1$ opens and thus prevents the possibility of the fast-speed winding being energized at the same time as the slow-speed winding. The motor now accelerates to its first speed, after which the car switch is moved to the fast-speed position. A circuit for the accelerating coil $C$ is now completed via +ve, car switch, two slowing terminal limit switches, $C$, $A1$ to -ve. The car switch contact arm bridges

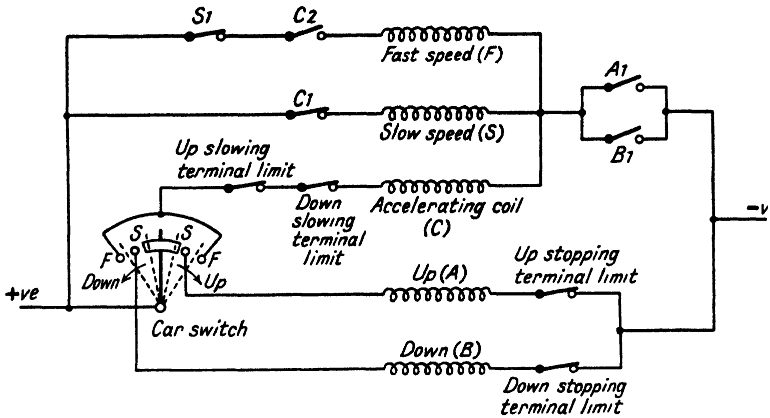



FIG. 219. ELEMENTARY TWO-SPEED CAR SWITCH CONTROL DIAGRAM

the slow- and fast-speed positions so that, when in the latter position, the coil $A$ remains energized. The opening of $C1$ and the closing of $C2$ disconnects coil $S$ and provides a circuit for coil $F$ respectively, the circuit for $F$ being via +ve, $S1$, $C2$, $F$, $A1$, and -ve. The contactor of coil $F$ (not shown) operates and connects the mains to the motor high-speed winding immediately the low-speed winding has been disconnected. The motor now runs at its maximum speed.

On approaching the desired floor, the car switch is returned to the slow-speed position, thus disconnecting coil $C$ which in turn disconnects $F$ by the opening of $C2$ and completes a circuit for $S$ when $C1$ closes. Stopping is thus performed from the slow speed. When the car has run sufficiently near to the floor at slow speed the car switch is centred, thus disconnecting

coil $A$ and cutting off the supply to the motor. The brake then automatically operates and stops the car.

Running in the down direction is performed in a similar manner except that the DOWN coil $B$ is energized instead of $A$.

The terminal limit switches shown automatically bring the car to rest at either terminal landing if the operator does not centre the car switch. Two switches—one slowing and the other stopping—are fitted near the bottom landing and two similarly near the top landing. These switches are operated by the movement of the car and may be fitted in the well, in which case they are operated by a cam on the car, or they may be situated in the motor room and operated by a camshaft driven from the car by a flyrope. The slowing switch operates a little in advance of the stopping switch so that the lower speed is reached before the stopping switch is operated.

**Four-floor Car Switch Controller with "Trulevel" Machine, Manually-operated Doors, and 2-phase, 3-wire A.C. Motor.** This controller, designed by the Express Lift Co., is suitable for a speed of up to about 200 ft. per min. The "Trulevel" machine is described and illustrated in Chapter XIII. Fig. 220 shows the wiring diagram for this controller, whilst Fig. 221 is a front view and Fig. 222 a rear view of the controller. The main motor of the "Trulevel" machine is a single speed 2-phase slip ring motor with three steps of rotor starting resistance and the small auxiliary motor is of the single speed 2-phase squirrel-cage type. The inductor system of levelling is employed and the operation of the controller is as described below. In the description $N/O$ means a normally open contact and $N/C$ a normally closed contact.

If all doors and other safety contacts are closed, the operation of the car switch to the UP position closes the car switch contact $CS\,U$ and relay 81 operates. $N/O$ contact 81 operates contactors 86 and 1 and the timing relays $T10$ and $T11$. $N/O$ contact 1 prepares the circuit to the main motor for the UP direction whilst another $N/O$ contact 1 and a $N/O$ contact 86 prepare the circuit for the brake coil. The clutch coil is energized by $N/O$ contact 86 and the clutch operates to isolate the levelling motor. Clutch contact $CL$ opens to enable relay $CPR$ to operate. Another $N/O$ contact 86 operates the timing relay $T5$. Contactor 6 now operates via $N/O$ $T5$, $N/O$ 1, $CPR$,

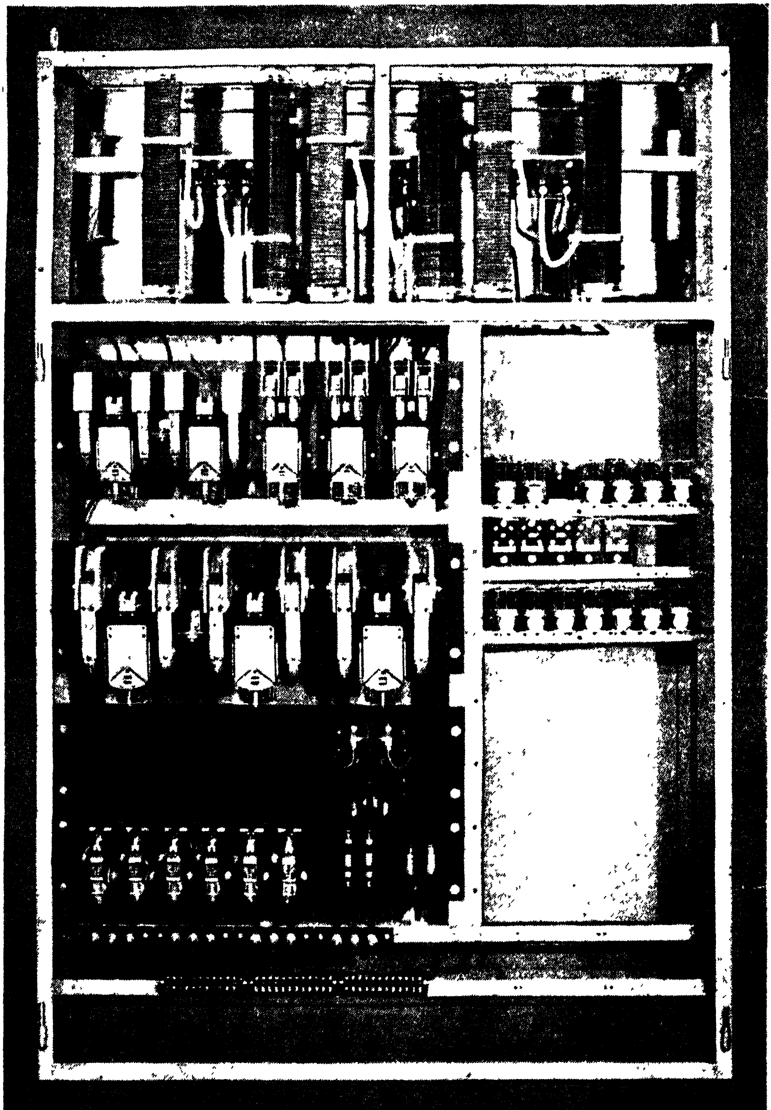


FIG. 221. CONTROLLER FOR FOUR FLOORS, CAR SWITCH CONTROL, WITH "TRULEVEL" MACHINE

(*Express Lift Co. Ltd.*)

FIG. 222 REAR VIEW OF CONTROLLER SHOWN IN FIG 221
(*Express Lift Co Ltd*)

$T10$ and $T11$. $N/C$ contact $CPR$ opens the circuit to contactors 91 and 92. $N/O$ contact 6 completes the brake and motor circuit, the brake lifts and the motor commences to rotate. The brake contact $BK$ opens and allows relay $BR$ to operate. $N/O$ contact $BR$ operates contactor 9, $N/O$ contacts of which short-circuit the first steps of rotor resistance. $N/C$ contacts of 9 open $T10$ circuit and $T10$ times out due to its parallel condenser and resistance circuit. $N/C$ contact $T10$ operates contactor 10 and $N/O$ contacts 10 short circuit the second step of rotor resistance. $N/C$ contact 10 opens $T11$ circuit and $T11$ times out. $N/C$ contact $T11$ operates contactor 11 and $N/O$ contact 11 short circuits the last step of rotor resistance after which the motor accelerates to full speed.

When the lift approaches the floor at which a stop is desired, the car switch is released and relay 81 is de-energized. Contactor 1 and relay 47 release and the motor is disconnected from the supply, and the brake is partially applied (the circuit to the brake coil is now via $N/O$ contact 6, $N/O$ contact 86 and resistance $R4$). Contactors 6 and 86 are held by $N/O$ contact $T4$. Relay $T4$ commences to time out, this circuit being opened by $N/O$ contact 47. As the car comes to rest, relay $T4$ times out and opens contactors 86 and 6. The release of $N/O$ contact 86 releases the clutch coil and applies full brake. The clutch is now released and connects the slow speed motor to the supply. The release of contactor 86 energizes the levelling inductor coils $1\,US$ and $1DS$. With the clutch de-energized and relay $CPR$ released, the circuit is complete to relays $LU$ and $LD$ via inductor contacts $1\,US$ and $1DS$. $N/O$ contacts $LU$ and $LD$ prepare circuits to the low speed reverser contactors 91 and 92 but $N/C$ contacts $LD$ and $LU$ also isolate these low speed reverser contactors. If we assume that the car stops below the level of the floor, then inductor $1DS$ will be embracing an inductor plate and the inductor contact $1DS$ will be open. Relay $LD$ will be released and its $N/C$ contact will then complete the circuit to the Up low speed contactor 91. $N/O$ contacts of $LU$ and 91 re-operate contactor 6 and $N/O$ contacts of 6 and 91 connect the low speed motor to the supply and energize the brake coil. The car then travels Up at slow speed.

At floor level the inductor plate enters inductor $1\,US$ and

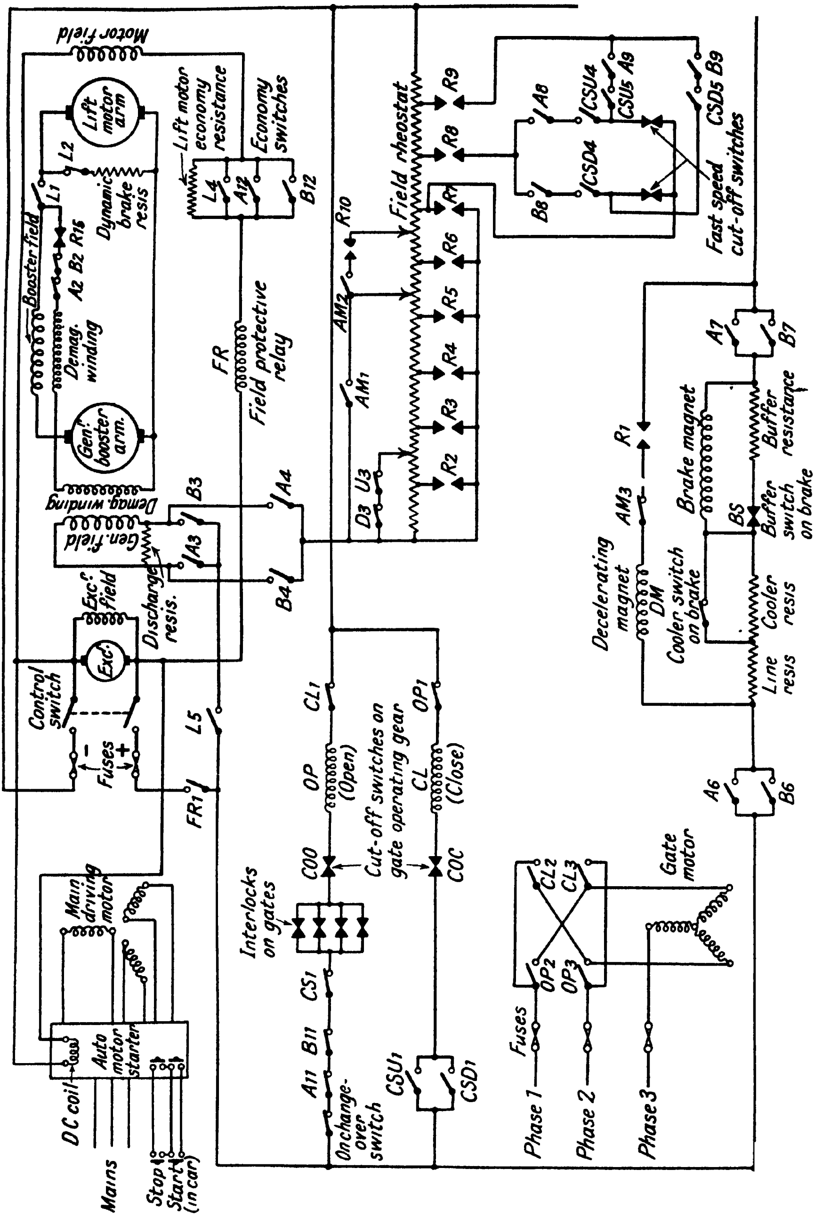
contact 1 *US* opens to release contactor 91 and relay *LU*. The low speed motor is disconnected and the brake applied to bring the car to rest at floor level.

If the car slides past the floor level during slowing, inductor 1*DS* moves beyond the inductor plate and therefore contact 1*DS* releases and completes the circuit to the down low speed contactor 92 via *N/O* contact of *LD* and *N/C* contact of *LU*. *N/O* contacts of *LD* and 92 operate contactor 6. The car returns to floor level and on the re-opening of inductor contact 1*DS* due to the plate entering 1*DS* inductor, relay *LD* and contactor 92 release.

Various protective features are incorporated in the controller. To ensure that the high speed motor is not energized until the clutch has operated to release the low speed motor, relay *CPR* is fitted. This operates when the clutch is fully operated, the clutch contact *CL* opening to remove the short circuit on *CPR*. If the clutch is energized but does not operate, *CPR* remains short circuited. When contact of 86 open circuits, the clutch relay *CPR* will be de-energized even if the clutch itself fails to release. *N/O* contact *CPR* in the circuit of line contactor 6 ensures that the high speed motor cannot be connected to the supply until the clutch has operated to disconnect the low speed motor from the machine. The timing relay *T*5 is operated by a *N/O* contact of the clutch contactor 86 and commences to time out on the release of that contactor. If the levelling operation is not completed within a predetermined time delay, relay *T*5 releases and opens the circuit to 91, and to 92 and to 6.

In Fig. 221 showing the front view of this controller the high speed rotor starting resistances are on the top shelf. On the next panel (left side) are from left to right, contactors 91, 9, 10 and 11, and on the next panel (left side) are, from left to right, contactors 1, 2, and 6. The bottom two panels accommodate contactor 86, the motor overload coils, and the fuses. On the right hand side are the various relays and timing condensers. The spaces above and below these relays would be occupied by additional equipment if the lift had been provided with automatic control.

**Four-floor Car Switch Controller with Gearless Motor, Variable Voltage Control, Straight-to-floor Levelling, and Power-operated Gates.** Fig. 223 is a diagram of Messrs.



Motor field
Lift motor arm
Lift motor economy resistance
Economy switches
L1
L2
Booster field
A2 B2 R16
Dynamic brake resis
L4
A12
B12
Demag. winding
Gen. booster arm.
Demag. winding
FR
Field protective relay
R10
Field rheostat
AM2
AM1
R2
R3
R4
R5
R6
R7
R8
R9
D3 U3
Gen. field
B3
A3
A4
B4
Discharge resis.
Exc. field
Exc.
Control switch
Fuses
L5
FR1
Main driving motor
Auto motor starter
DC coil
Mains
Stop
Start (in car)
CL1
OP1
OP (Open)
CL (Close)
Cut-off switches on gate operating gear
COO
COC
Interlocks on gates
CS1
B11
A11
Onchange-over switch
CSU1
CSD1
Fuses
Phase 1
Phase 2
Phase 3
OP2
OP3
CL2
CL3
Gate motor
A6
B6
Line resis
Cooler resis
Cooler switch on brake
Decelerating magnet
DM
AM3
R1
Brake magnet
BS
Buffer switch on brake
Buffer resistance
A7
B7
A8
B8
CSD4
CSU4
CSU5 A9
CSD5 B9
Fast speed cut-off switches

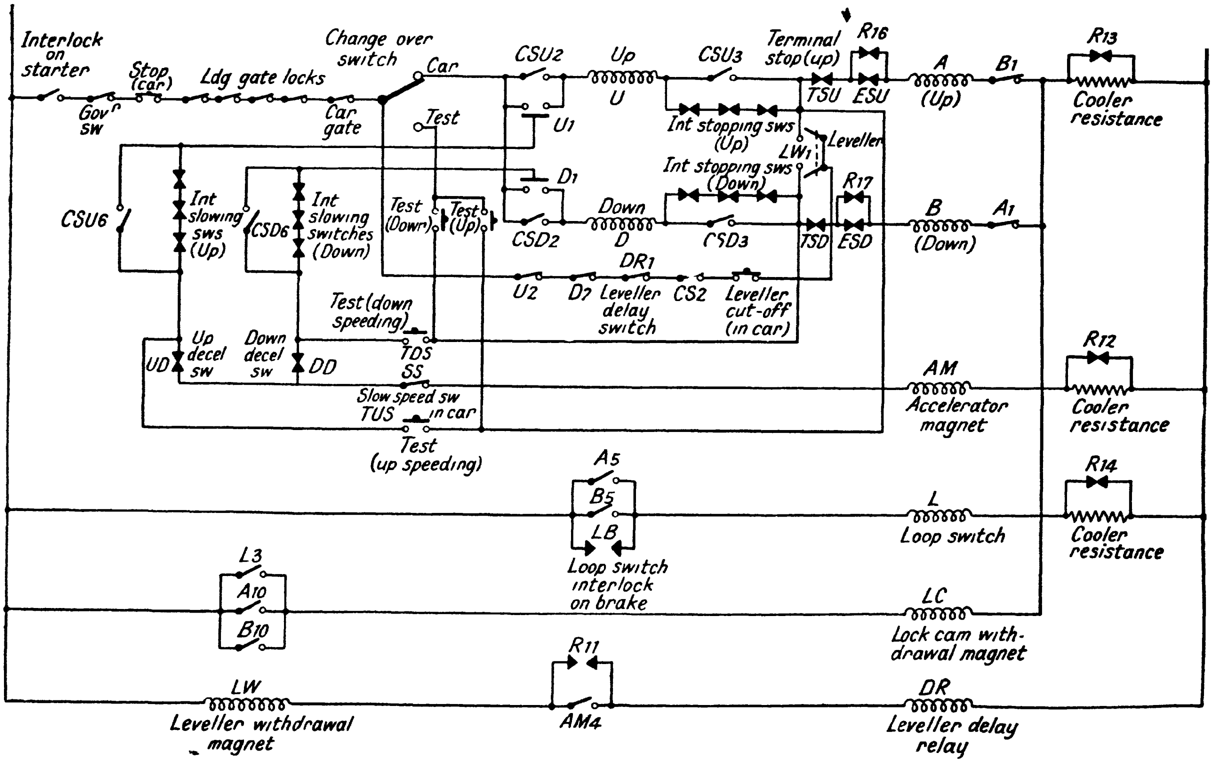



FIG. 223. CAR SWITCH VARIABLE VOLTAGE GEARLESS MOTOR CONTROLLER
Four floors

Wm. Wadsworth & Sons' controller of this type. A brief description of the equipment, will, no doubt, assist in following the operations of the control circuits.

The motor generator set runs constantly the whole time the lift is in service, whilst the direct coupled exciter provides the direct current necessary for energizing the brake coils, control gear magnets, and the field coils of the generator and the slow-speed lift motor. The generator armature is coupled, with one intermediate switch to the lift motor armature so that the only current handled by the lift controller is that of the generator field, brake and control circuits. The driving motor of the set is an ordinary squirrel-cage induction motor with a synchronous speed of 1 500 r.p.m. for the smaller sets, and 1 000 r.p.m. for the larger ones. Starting of the motor generator set is accomplished by one or more of the following methods—

(1) Start and stop buttons in the car.

(2) Starting when the car switch is moved to the starting position. Automatic stopping is adjustable up to ten minutes after the lift was last used.

(3) Starting when the lift operating push (car or landings) is pressed momentarily and stopping performed automatically as in (2).

The generator incorporates in itself a series connected booster, the function of which is to increase or decrease the voltage normally produced by the generator by independent means with the increase or decrease of load. This gives the main lift motor a definite rising speed characteristic with increase of load. The isolation of the booster winding on the generator field system renders it impossible for regenerative current to overpower the main field and allow the car to "run away." The lift motor is a shunt wound machine, the field windings of which are partially energized all the time the lift is in service. When the lift is required, the field strength is immediately brought up to full value. The armature speed is 8[illegible] r.p.m., and the driving sheave 24 in. in diameter. A speed of 3 [illegible]p.m. is possible for levelling purposes. These figures correspond to running and levelling speeds of approximately 500 and 20 ft. per min. respectively. The brake drum and sheave are directly coupled to the armature spider without the use of keys. Each of the two brake bands is entirely independent of

the other, even for spring pressure. The action of the brake is controlled, so that release is gradual whilst application takes place in two stages: the first a fairly quick action to take up the clearance, and the second a squeezing action, achieving its maximum after the car has come to rest.

The patented feature of the controller is the means employed to produce "distance" as distinct from "time" acceleration and deceleration. It is, therefore, possible to obtain equal rates of acceleration and deceleration irrespective of loads, and thus prevent waste of time by running long distances at slow speed. The equipment for achieving this consists of a multiple contactor rheostat operated by means of a camshaft which is coupled to the winding gear, and at appropriate times is made to move forwards and backwards in unison with the motion of the car, opening and closing the requisite contactors to produce smooth acceleration and deceleration of the car. All $R$ contacts shown in the wiring diagram are operated by means of this mechanically driven camshaft. The $CS$ contacts on the car switch are operated by movement of the car switch in either direction, whilst $CSU$ contacts are operated in the UP direction of the car switch only and $CSD$ contacts are operated when the car switch is moved to the DOWN direction.

To start the lift, the attendant presses the starter button fitted in the car, and the motor generator set automatically starts. When the signal lamp on the push button plate assumes full luminosity the field protective relay has closed circuit and the lift is ready for operation. The circuit shown is for four floors, and it will be assumed that the car is at the bottom floor and the attendant, after starting the set, moves the car switch to the UP position. The operation of the car switch completes a circuit for the close gate relay $CL$ from +ve pole of exciter via $FR1$, $CSU1$, cut-off switch $COC$, $CL$, $OP1$ to -ve. Both $CL2$ and $CL3$ close and connect the mains to the gate motor, which operates to close the landing and car gates. $COC$ disconnects the circuit for $CL$ when the gates have closed. If it is desired to arrest the motion of the gates when closing and to re-open them, it will be noted that this may be done by returning the car switch to the OFF position and thus opening $CSU1$. When the gates are closed, the lift circuit is completed and the UP relay magnet $U$ operates via +ve,

starter interlock (now closed), governor switch, car stop, landing gate contacts, car gate, change-over switch, *CSU*2, coil *U*, *CSU*3, *TSU*, *ESU* (emergency stop on car), Up coil *A*, *B*1, *R*13 to –ve. The energizing of coils *U* and *A* causes all the *U* and *A* contacts to operate. Current from the exciter passes to the lift motor field via *FR* and *A*12 and to the loop switch coil *L* via *FR*1, *A*5, and *R*14. The closing of *L*1 causes the generator to give current to the lift motor armature and at the same time the brake is released on the operation of *A*6 and *A*7, and the opening of *L*2. The closing of *L*4 and *A*12 short-circuits the economy resistance which is left in circuit with the main lift motor field when the lift is at rest, and this increases the motor field strength and starting torque to their maximum values. Coil *LC* is energized via *A*10 and thus withdraws the lock cam beyond reach of the gate lock strikers until the floor at which a stop is desired is reached. The generator field is energized via *FR*1, *L*5, *A*3, *A*4, and the field rheostat. Simultaneously the accelerating magnet *AM* is fed via the change-over switch, *U*1, *CSU*6, *UD*, *SS*, coil *AM*, and *R*12. The accelerating magnet applies pressure to the accelerating clutch, and by closing *AM*1 increases the initial strength of the generator field. Contact *AM*2 also closes and energizes *R*10 ready for the operation of the camshaft. The energizing of *AM* causes the friction clutch on the right-hand side of the controller to close, and rotation is transmitted from the hoisting sheave to which the clutch is connected by a chain drive. The rheostat camshaft is therefore rotated to the full extent of its movement in unison with the car motion, and the *R* contacts are thus operated. Rheostat contacts *R*1, *R*2, *R*3, *R*4, *R*5, *R*6, *R*10, *R*7, *R*8, and *R*9 close quickly in the order given above, and the generator field strength is brought up to full value so that the motor then runs at the full speed of 80 r.p.m. After the camshaft completes its full travel the clutch is allowed to slip. *AM*4 energizes *DR* and *LW*, the latter withdrawing the levelling switch *LW*1 beyond reach of the intermediate floor cams. The operations described above take place in about two seconds, and the generator voltage induced in the armature and transferred to the lift motor increases rapidly but, due to the lag of magnetic flux, the voltage is produced in a curve devoid of steps, thus ensuring that a smooth acceleration is

obtained. Contacts *R*12, *R*13, and *R*14 open and introduce economy resistances into the accelerator, reversing, and loop switch magnet circuits respectively. The demagnetizing protecting switch *R*15 on the camshaft opens in readiness to apply current to the demagnetizing winding when deceleration is completed. Interlocking safety switches *R*16 and *R*17 open in readiness to apply the automatic emergency stopping switch on the car (*ESU* and *ESD*) before the terminal levels are reached in the event of the controller failing to operate normally when approaching the stopping levels.

If a stop is desired at the fourth floor, the attendant releases the car switch after passing the third floor, and the switch automatically returns to the OFF position. The opening of *CSU*4 and *CSU*5 re-inserts resistance direct into the generator field, and the opening of *CSU*6 removes the short circuit from the intermediate slowing switch bank of the floorsetter gear. Similarly, *CSU*3 removes the short circuit from the stopping switch bank. The intermediate slowing switch between the third and fourth floors is the next switch to operate, having been set to act at the correct decelerating distance for the fourth floor. This de-energizes *AM*, and the closing of *AM*3 energizes the decelerating magnet *DM*, thus operating the two friction clutches on the left-hand side of the controller. Rotation is then transmitted from the main hoisting sheave as before, so that the camshaft is rotated in the opposite direction to that for acceleration until it arrives back at the start position. At this point the decelerating magnet is automatically de-energized by the opening of *R*1, and releases the mechanism which resets itself ready for the next operation. Thus resistance is re-inserted into the field by the opening of *R*2–*R*9 and the car speed is reduced to the levelling speed of about 20 ft. per min. The next switch to open is the intermediate stopping switch between floors 3 and 4, and this disconnects coils *U* and *A*. The opening of *A*6 and *A*7 de-energizes the brake and the consequent closing of *BS* inserts a buffer resistance to ease the action of the engagement of the shoes with the drum. Demagnetizing switch *A*2 closes, and when the motor torque is reduced to zero and the brake bands have gripped the drum, *LB* opens and cuts off *L*. This causes *L*2 to close and apply the dynamic brake. When the car finally comes to rest and all

the controller contacts are in the OFF position, the lock cam withdrawal magnet *LC* is de-energized. The cam then falls into position and releases the locking gear on the electric locks, and at the same time causes the interlock switch on the lock to close. *OP* is then energized, *OP*2 and *OP*3 close, and the gate motor automatically opens the gates. When the gates are fully opened, *COO* opens and stops the motor, the gates remaining fully open.

In the event of the levelling due to the operation of the floor selector being inaccurate, it is corrected by the leveller switch *LW*1 mounted on the car. This switch is of such a design that its operation is independent within wide limits of the lateral movement of the car. Hence worn guide shoes or side motion of the car guides do not impair the accuracy of stopping and levelling. If the car levels too low, the switch *LW*1 engages the lower level of a ramp in the well and is operated in such a direction that when *DR*1 (lagged) closes shortly afterwards when the motor has stopped, the UP coil *A* is energized via change-over switch, *U*2, *D*2, *DR*1, *CS*2, leveller cut off, *LW*1, *TSU*, *R*16, *A*, *B*1, and *R*13. This causes the car to move upwards at slow speed until *LW*1 engages with the ramp second level and is thus cut off, thereby de-energizing *A* and correctly levelling the car. Similarly the DOWN coil *B* is energized by *L*1 if the car stops too high.

The slowing and stopping switches are incorporated in the floor selector, which is situated in the motor room. This selector consists of a worm-driven shaft which is caused to rotate by the up and down motion of the car. To the car is attached a steel rope passing round a sheave direct coupled to the worm gear of the selector, and a suitable reduction in speed is introduced so that the movement of the shaft represents the car's motion on a small scale. Attached to the shaft are roller arms which engage with the quick-break slowing and stopping switches.

The operations for a down journey are similar to those described above, except that the switches involved are those in the DOWN circuits.

If the attendant omits to move the car switch to the stopping position when approaching the terminal floor, the operations for bringing the car to rest at the end of travel in a normal manner are initiated in a multiple contact switch situated on

top of the car. This multiple contact switch incorporates a total of eight switches, four for each direction of travel, each switch being operated by its own cam in the well. When the car approaches, say, the top terminal landing, the Up fast-speed cut-off switch is opened by engaging with a cam in the well, and this brings about the first reduction in car speed by introducing resistance in the generator field. After travelling a short distance at the reduced speed, the Up decelerating switch on the car (*UD*) is opened by engagement with another cam in the well and thus de-energizes *AM*, which in turn releases the accelerator clutch and energizes *DM* by the closing of *AM*3. Thus additional resistance is inserted in the generator field as described above, and the slow levelling speed is reached. The terminal limit switch *TSU* on the car finally stops the car's motion by engaging a cam in the well and cutting off coils *U* and *A*. The brake operates and the car stops as described above. Emergency switch *ESU*, the fourth switch of the multiple control switch, definitely cuts off coil *A* before the terminal landing is reached, even if the other switches fail or the controller fails to respond to them and normal deceleration has not taken place.

In an emergency, momentary pressure on the car stop button de-energizes the reverser coil and the accelerator magnet *AM*, the latter causing the camshaft to be returned to the starting position under the influence of a counterweight, thus bringing the car to rest rapidly and smoothly. Failure of the main supply, unsafe weakening of the motor field, or operation of the overspeed governor has an exactly similar action.

Slow-speed switch *SS* fitted in the car permits of the operation of the car at the slow levelling speed throughout its travel to facilitate testing and inspection. This is effected by *SS* cutting off the accelerator magnet *AM*. The change-over switch fitted on the controller enables the lift to be operated from the motor room in the up or down directions at slow or fast speed by operation of the appropriate test buttons. The cooler switch fitted to the brake inserts the cooler resistance after the brake plunger has made its stroke.

## AUTOMATIC CONTROLLERS

As the name implies, this type of controller is one in which the operations of starting, accelerating, and stopping the lift

are performed automatically after a landing or car button has been pressed. The selection of the desired floor is effected by means of floor relays and direction switches; one relay and switch for each floor served. On pressing a car or landing button the corresponding floor relay is energized, and at the same time the main supply is connected to the motor. The floor relay is disconnected when the car reaches the desired floor and opens the direction switch.

**Elementary Automatic Controller.** An elementary automatic

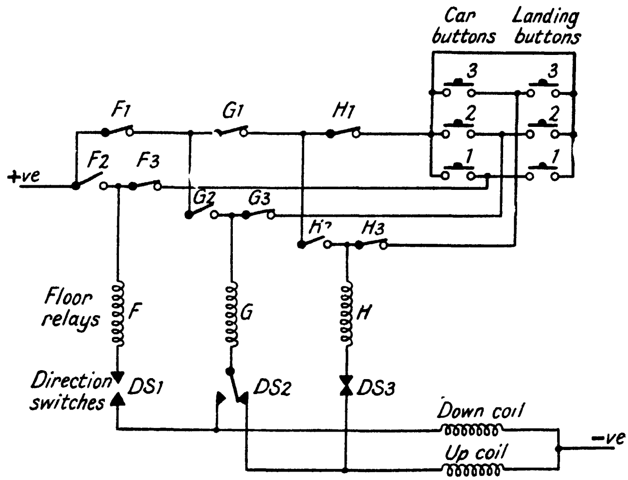



FIG. 224. ELEMENTARY DIAGRAM OF AUTOMATIC CONTROLLER

control diagram for three floors is shown in Fig. 224. A single-way direction switch is required at each terminal floor, and a two-way switch at each intermediate floor. As the car passes an intermediate floor, the direction switch is changed over from the UP direction to the DOWN direction if the car is travelling upwards, and vice versa if travelling downwards. A floor selector fitted in the motor room may be employed to perform the same functions as those of the direction switches. In the diagram the car is at the bottom landing No. 1, and the direction switch *DS*1 at that floor is open. All direction switches above the car have joined their floor relays to the UP coil. If the landing button No. 3 or car button No. 3 is now pressed a circuit for the third floor relay *H* will be completed via +ve,

$F1$, $G1$, $H1$, No. 3 button, $H3$, coil $H$, direction switch $DS3$, UP coil, and -ve control feed. Contact $H2$ immediately closes and a circuit for coil $H$ is then provided from +ve, $F1$, $G1$, and $H2$, this circuit being independent of the buttons. Hence, only momentary pressure on a button is necessary to operate and lock the circuit for coil $H$. The opening of contacts $H1$ and $H3$ disconnects the car and landing buttons and prevents interference with the motion of the lift by the operation of any other button. When the UP contactor (not shown) operates on the energizing of the UP coil, the supply is connected to the motor and the lift begins to move. As the car travels upwards and passes floor No. 2 a ramp, fixed to the car, operates direction switch $DS2$ and causes it to make contact on the DOWN coil side, thus preparing a circuit for the down direction of travel. On nearing floor No. 3, the car ramp opens switch $DS3$, thus cutting off the circuit for the UP coil and causing the UP contactor to open. The brake then operates and stops the car at the landing. If the car had been called to floor No. 2 instead of floor No. 3, then floor relay $G$ would have been energized and its contacts $G1$, $G2$, and $G3$ operated instead of relay $H$ and its contacts. Operation in the down direction is similar except that the DOWN coil is energized instead of the UP coil. For example, if the car is now called down to floor No. 1, floor relay $F$ would be energized via +ve $F1$, $G1$, $H1$, landing button No. 1, $F3$, $F$, $DS1$, and DOWN coil to -ve, thus operating contacts $F1$, $F2$, and $F3$.

**Semi-automatic Single-speed Controller.** The wiring diagram shown in Fig. 225 is suitable for a single-speed goods or service lift with two landings and UP, DOWN, and STOP buttons fitted on each landing. The supply is three-phase, and a slip-ring motor with one step of starting resistance is used. If the car is at the bottom landing, the operation of the circuit is as follows. The down terminal limit switch is open and it will be noted that pressure on either DOWN button ($D$) will have no effect as it is impossible to complete a circuit for coil $B$ by operating a DOWN button. If an UP landing button ($U$) is pressed, the circuit for coil $A$ is via +ve the door and car contacts, stop buttons $S$, change-over switch, operated $U$ button, UP terminal limit switch, coil $A$, interlock $B3$, rotor contactor coil $R$, and brake economy resistance to -ve. The

closing of $A1$ and $A2$ energizes the brake coil and releases the brake. Contactor $R1$ closes a few seconds later and the motor accelerates to full speed corresponding to, say, 100 ft. per min. As soon as the brake has released, the brake economy switch opens and inserts the economy resistance. When the car reaches the upper floor the UP terminal limit switch fitted in the well is opened by a ramp on the car, and the car then stops due to the de-energizing of coil $A$ and the opening of contactor $A5$.

A circuit for coil $B$ is similarly provided on the operation of a DOWN button.

The change-over switch permits of the operation of the car from the motor room by moving the switch to test and depressing a test button.

Contact $P1$ is lagged for a period of from $1\frac{1}{2}$ to 2 times of a complete journey and by cutting off the control circuit after this period so prevents the motor from being connected to the mains in the event of a brake coil failure.

**Fully-automatic Single-speed Controller, Four Floors with Prelocks and Inductor Stopping.** The diagrams in Fig. 226 and Fig. 227 show the principle of the Express Lift Co.'s controller for a speed of about 100 ft. per min. employing a squirrel-cage motor with starting resistance. The selector and inductor described in Chapter XIII are both used in this installation. In the description below, $N/O$ means normally open and $N/C$ normally closed.

If the lift is standing at an intermediate floor both relays 23 and 24 are operated and their contacts prepare the circuits for the UP direction relay 81 and the DOWN direction relay 82. Assume that the car is standing at the second floor and then selector contacts $1S$ and $2S$ will be open and if the doors are closed relay 43 will be operated. If a passenger opens the doors and enters the car, relay 43 releases, $N/C$ contact 43 closes and operates relay $T2$ and $N/C$ contact. $T2$ then opens the landing button feed. On closing the door, relay 43 re-operates and $N/C$ contact 43 opens and cuts off relay $T2$ which commences to time out after about 5 seconds. This is effected by the condenser and resistance circuit in parallel with the relay. If the passenger operates the 3rd floor push button, relay 103 and 81 operate and self hold via $N/O$ contact 103. $N/O$ contact 81 prepares the circuit for contactor 1 and a second $N/O$

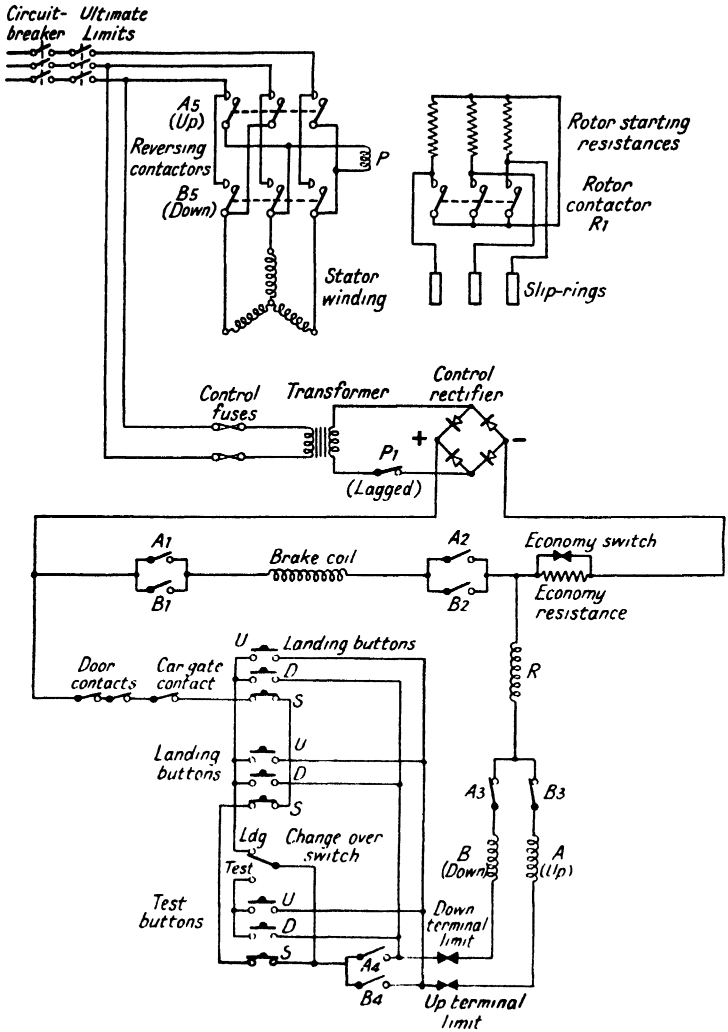



FIG. 225. SEMI-AUTOMATIC CONTROLLER FOR SERVICE LIFT

contact 81 operates relay 87. The retiring cam, relay $T1$ and relay 83 now all operate. $N/C$ contact $T1$ cuts off the button feed, whilst $N/O$ contact $T1$ shorts the selector reducing resistance $R3B$. $N/O$ contact $T1$ operates relay $T2$ and $N/O$ contact $T2$ shorts the $ZS$ inductor reducing resistance $R3A$. The retiring cam locks the doors and prelocks the circuit to contactor 1. The main contacts of contactor 1 prepare the

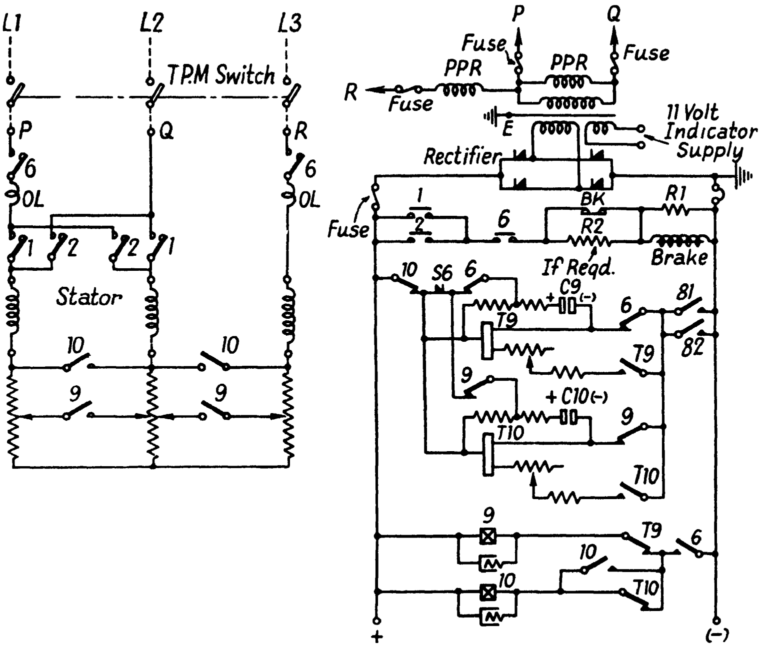



FIG. 226. POWER CIRCUIT FOR AUTOMATIC SINGLE-SPEED CONTROLLER, FOUR FLOORS, WITH PRELOCKS AND INDUCTOR STOPPING

motor windings for the UP direction and $N/O$ contact 1 prepares the brake circuit. $N/O$ contact 81 operates relays $T9$ and $T10$ and timing condensers $C9$ and $C10$ then charge. $N/C$ contacts $T9$ and $T10$ open circuits of contactors 9 and 10 which have not yet operated, whilst $N/O$ contacts $T9$ and $T10$ complete the circuit to contactor 6 which operates. The brake now lifts and the motor accelerates. The brake economy resistance $R2$ and switch $BK$ are fitted if required. $N/C$

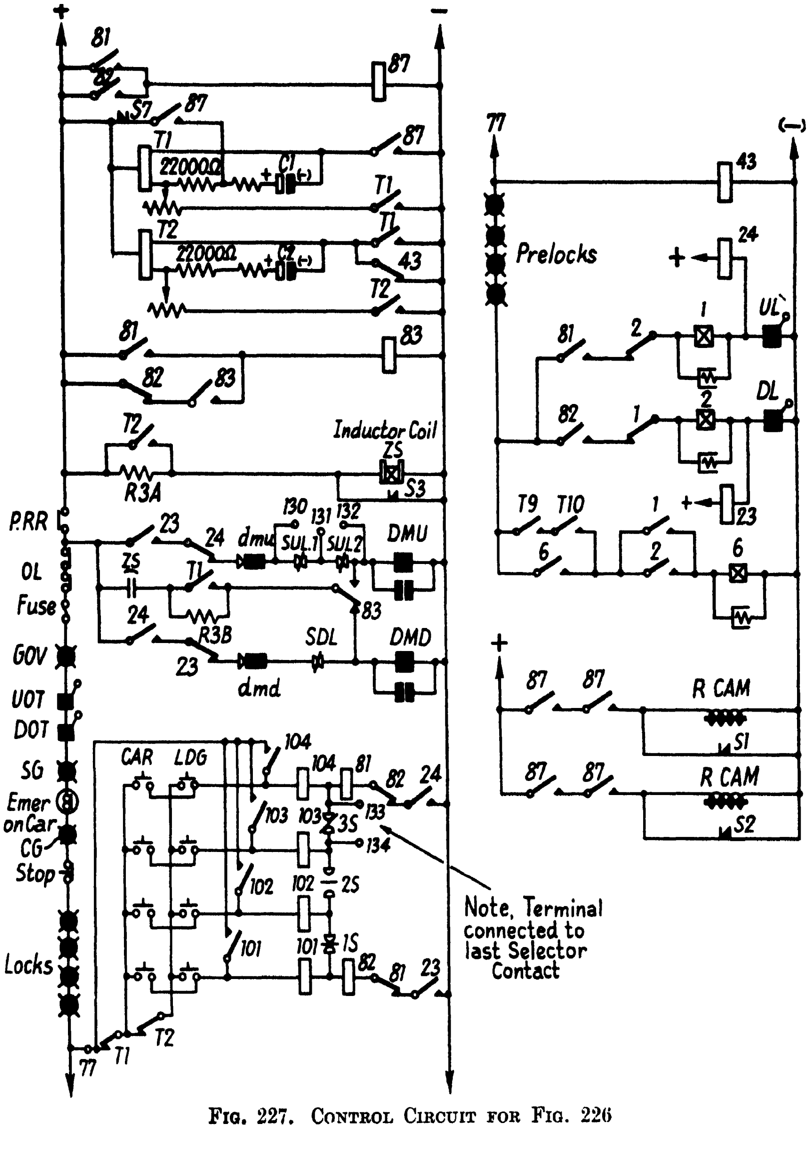



Fig. 227. Control Circuit for Fig. 226

contact 6 opens the timing circuit of $T9$ which times out and then $N/C$ contact $T9$ operates contactor 9. The main contacts of contactor 9 short out the first step of starting resistance. Similarly the main contacts of contactor 10 short out the second step of starting resistance later, after $T10$ times out.

On leaving the second floor, inductor contact $ZS$ closes, the selector steps to position 4 and contact $1S$ closes. The operation of the selector is described in Chapter XIII. On approaching the 3rd floor, contact $ZS$ again closes, selector steps to position 5 and contact $3S$ opens. Relays 103, 81 and 87 all release. $N/O$ contact 81 releases contactor 1 and contacts of 1 open the motor circuit and release the brake. $N/O$ contact 1 releases contactor 6. The car comes to rest at the floor, the retiring cam advances and opens the prelocks, $T1$ times out to insert the selector reducing resistance, and restores the push button feed. $T2$ starts timing out, but when the passenger opens the doors, relay 43 releases and $N/C$ contact 43 maintains $T2$. When the passenger leaves the car and closes the doors, relay 43 re-operates to open $T2$. After 5 seconds $T2$ times out to restore the landing push button feed and the lift is now ready to accept landing calls.

At the terminal floors the stopping is controlled by the limit switches $UL$ and $DL$ which open the circuit to contactors 1 and 2 and relays 23 and 24.

Operation in the Down direction is similar when relay 82 operates.

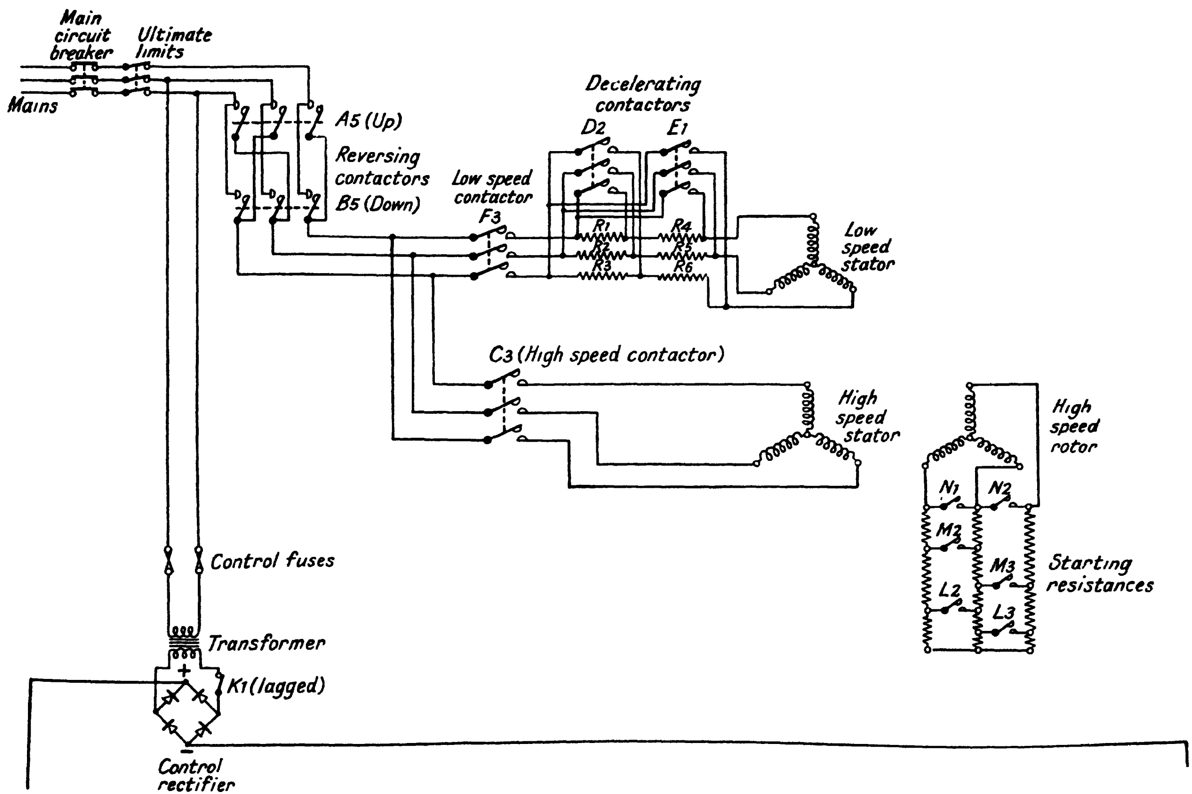
**Fully-automatic Two-speed Controller with Tandem Motor.** The diagram shown in Fig. 228 is for an automatic controller with the car operating between five floors. A two-speed tandem motor is employed and the controller is suitable for car speeds up to about 300 ft. per min. Starting and full-speed running are performed on the high-speed slip-ring section, whilst the slow running speed of, say, one-sixth the fast speed is obtained from the squirrel-cage section.

If the car is at the bottom landing and the top landing button No. 5 is pressed to bring the car to that floor, the circuit for the Up contactor coil $A$ is via landing gate contacts, car stop button, car gate contact, change-over switch, $V1$, $W1$, $X1$, $Y1$, $Z1$, $J1$, $S$, landing button No. 5, $V2$, floor relay $V$, No. 5 stopping switch, coil $A$, and interlock $B1$. Contact $A1$ on

opening ensures that $B$ cannot operate; $A3$ and $A4$ on closing energize the brake coil and release the brake. Coils $H$, $J$, and $K$ are also fed by contacts $A3$ and $A4$. The opening of $V2$ and closing of $V3$ transfers the feed of coils $V$ and $A$ from the change-over switch direct to floor relay $V$, thus cutting out the buttons and preventing interference when the car is in motion. The closing of $V4$ provides a parallel circuit for the high-speed relay $G$ via $V4$, slowing switch No. 5, and slow test button. Contact $G1$ opens and guards against the low-speed contactor $F3$ operating, whilst $G2$ closes and provides a circuit for $C$ via $A2$, $G2$, and $F1$. Reversing contactor $A5$ has operated, and with the energizing of coil $C$ contactor $C3$ closes and the mains are then connected direct to the high-speed stator, thus causing the motor to rotate. The closing of $C2$ provides a circuit for the first rotor contactor coil $L$, whilst $L2$ and $L3$ cut out the first step of rotor resistance. After a brief interval $L1$, which is lagged, closes and energizes $M$, thus causing $M2$ and $M3$ to cut out the second step of rotor resistance. Similarly, $M1$ provides a circuit for $N$ so that $N1$ and $N2$ cut out the last step of resistance and the lift attains its full speed of, say, 300 ft. per min.

When the car approaches floor No. 5, slowing switch No. 5 of the floor selector is opened automatically. This cuts off the supply from coil $G$, and the opening of $G2$ disconnects the high-speed coil $C$, with the result that contactor $C3$ opens. The closing of $G1$ energizes $F$, and contactor $F3$ closes, thus connecting the mains to the low-speed stator via buffer resistances $R1$–$6$. On closing, shortly afterwards, $F2$ feeds coil $D$, and contactor $D2$ short-circuits the first steps $R1$, $R2$, and $R3$ of the buffer resistance. $D1$ is slightly lagged, and on closing energizes coil $E$, and thus the second steps of buffer resistance $R4$, $R5$, and $R6$ are short-circuited. Alternatively, these resistances may be short-circuited by a single magnet as shown in Fig. 51. The lift is now running at the slow levelling speed of, say, 50 ft. per min. On approaching still nearer to floor No. 5, the stopping switch No. 5 is opened and thus disconnects coil $A$, which in turn causes contactor $A5$ to open. The supply is now cut off from the slow-speed section and the opening of $A3$ and $A4$ causes the brake to operate and the car to level at the floor.

Operation in the down direction is similar to that described


Main circuit breaker
Ultimate limits
Mains
A5 (Up)
Reversing contactors
B5 (Down)
Low speed contactor
F3
Decelerating contactors
D2
E1
R1
R2
R3
R4
R5
R6
Low speed stator
C3 (High speed contactor)
High speed stator
High speed rotor
N1
N2
M2
M3
L2
L3
Starting resistances
Control fuses
Transformer
K1 (lagged)
+
−
Control rectifier

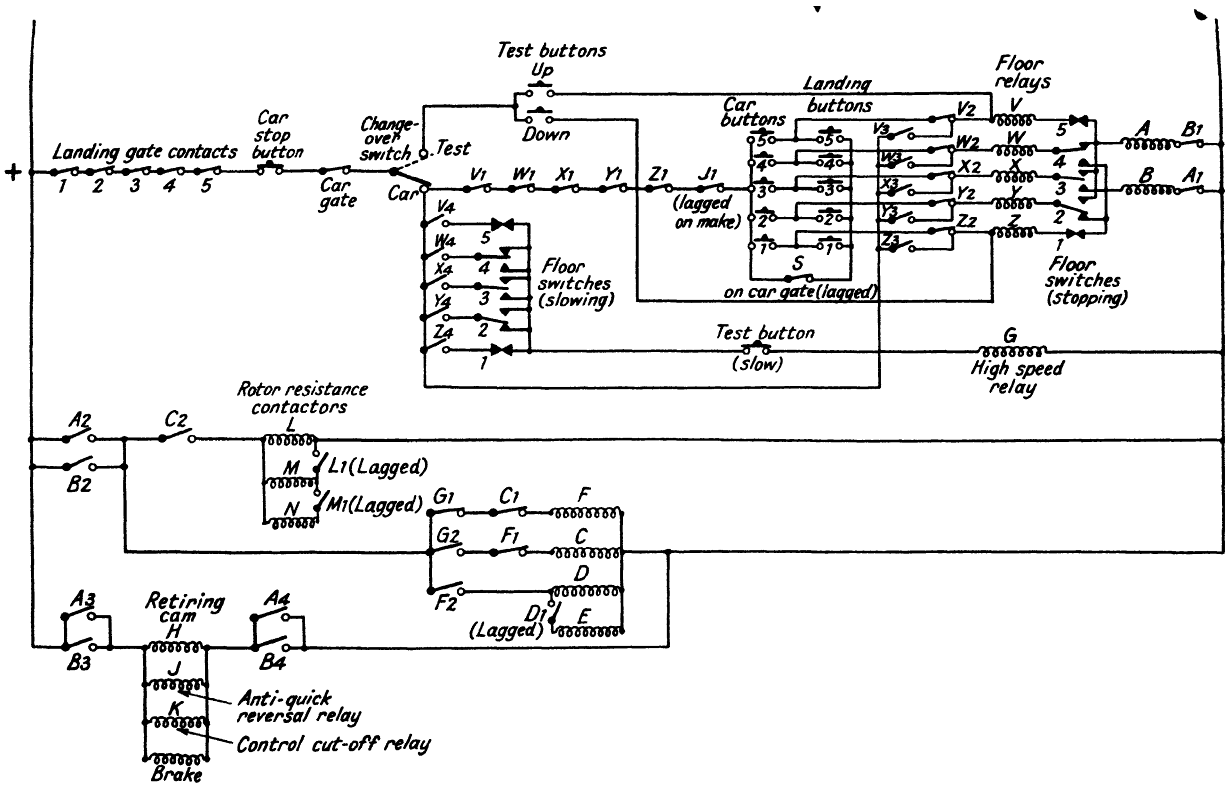



FIG. 228. TWO-SPEED AUTOMATIC CONTROLLER WITH TANDEM MOTOR

above, except that coil $B$ is energized and contactor $B5$ operated instead of $A5$.

The up and down test buttons enable the car to be operated from the motor room either at fast or slow speed, the latter if the slow test button is also operated.

Various protective and non-interference devices may be incorporated in the controller. In the diagram shown, $H$ is the retiring cam coil and is energized when either the UP or DOWN contactor operates, and by withdrawing the cam on the car beyond reach of the gate lock striker prevents a landing gate from being "snatched" open as the car passes. The coil releases the cam when the reversing contactor opens. Contact $J1$ on the main control feed is lagged on make for a period of a few seconds, sufficiently long to enable the motor to come to rest after the reversing contactor has opened, and this prevents the motor from being reversed before it has stopped rotating. The control cut-off contact $K1$ disconnects the control supply if the motor is connected for a period of more than about $1\frac{1}{2}$ times a full journey. Associated with the car gate contact is a contact $S$, lagged for about five seconds, and this disconnects the landing buttons for this period after a passenger has entered the car. The ultimate limits cut off both motor and control circuits in the event of the car over-travelling the terminal landings.

## Down Collective Control with Single-speed Motor, Rheostatic Starting (Express Lift Co. Ltd.)

1. GENERAL DESCRIPTION

Pushes are provided in the car corresponding to each floor served. A single call push is fitted at each landing. Registration of a landing call is indicated by illumination of the push.

All calls which are registered from either the car or landings are stored in the system. Car calls are answered successively by the car which reverses at the highest call.

Landing calls are answered successively by the car when it is travelling in the DOWN direction only. The car does not stop for landing calls when it is travelling in the UP direction, with the exception of the highest landing call which is answered only if there are no car calls ahead of this landing call.

After all calls have been answered, the car automatically returns to the parking floor and remains there with the doors closed.

The circuit diagram is shown in Fig. 229 and the controller in Fig. 230.

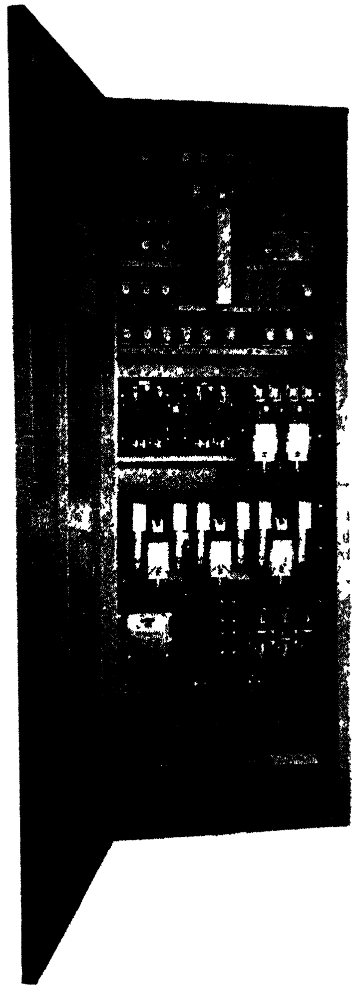


Fig. 230. Controller for Down Collective Control (*Express Lift Co. Ltd.*)

2. Sequence of Operations

*Car Calls.* Car call relays 1*C*, 2*C*, etc., are operated by the corresponding pushes in the car via winding *B–A*, a *N/C G* contact and relay *CP*. These relays selfhold via their own *N/O* contacts, a *N/O* 48 contact, *N/O T5A*, *N/O FC* and *N/C MAA*.

A car call relay is cancelled by the opening of a *N/O* 48 contact when the car stops.

The *N/C G* contact in series with each car push prevents a car call from being registered for a floor while the car is in the zone of the floor. Without this feature, the registration of the car call would cause the car to stop away from floor level if the call was registered while the car was travelling away from the floor and while it was still in the floor zone.

*Landing Calls.* Landing call relays 201, 302, 303, etc., are operated by the corresponding landing pushes via winding *B–A*, *N/O FC* and the *N/C G* contact or a *N/O* 61 contact. These relays hold via their own *N/O* contacts, winding *B–A* and a *N/C G* contact or a *N/O* 61 contact. They are also held via winding *D–C*, their own contacts and *N/O* 26.

The *N/O* 61 contact in series with winding *B–A* is for a similar purpose to that described above. (See next section for description of 61 and 61*A*.)

A landing call relay is cancelled by the opening of *N/O* 26 in series with winding *D–C* and by the opening of *N/O* 61 or *N/O* 61*A* in series with winding *B–A*.

Registration of a landing call is indicated by illumination of the push.

*Relays* 61 *and* 61*A*. These relays are operated for the Up direction via *N/C* 2 and *N/O* 26. They are released for the Down direction by the opening of *N/C* 2.

Contacts of these relays in the negative feed to winding *B–A* of the landing call relays enable a call relay to be operated for opening the doors at the floor at which the lift is standing. When the doors have fully opened, *N/O* 26 releases 61 and 61*A* and so cancels the call relay.

A second function of the contacts of the above relays is to enable landing calls to be registered when the lift is travelling in the Up direction, even though the lift may be in the zone of the floor for which the call is registered.

When the lift is travelling Down, 61 and 61*A* are released, and a landing call cannot be registered for a floor while the lift is in the floor zone.

*Selector Circuit and* G *Relays.* For a description of the operation of the Selector, see Chap. XIII.

With inductor *ZS* energized, the selector is stopped by the closing of *N/O LS* contacts each time the car passes a *ZS* plate in the well (*LS* is operated by *ZS* inductor contacts).

The positions over which the various contacts open and close are shown on the Selector Chart.

Selector contacts 1*P*, 2*P*, etc., close to operate successively relays 1*G*, 2*G*, etc., as the car passes through the corresponding floor zones. (For example, 1*G* will be operated while the car is at the first floor.)

The operation of contacts 1*S*, 2*S*, etc., is described later.

*Directional Set-Up.* The direction in which the car will travel is determined by the operation of relays 81 (Up direction) and 82 (Down direction). Contacts of these relays control the main reversing contactors 1 and 2.

Relays 81 and 82 are controlled by contacts of the call relays

in conjunction with the selector *S* contacts. Selector contacts 1*S*, 2*S*, etc., are arranged in a chain and a contact is open on each side of the feed to the chain, corresponding to the position of the car. For example, with the car at the second floor, 1*S* and 2*S* will be open.

The feeds to the chain are via *N/O* contacts of the call relays. Hence a call above the car will operate 81 and a call below the car will operate 82.

Relays 81 and 82 are electrically interlocked, so that the operation of one prevents the operation of the other. Therefore, with a number of calls stored in the system, either 81 or 82 will remain operated, and the car will continue its direction of travel until it has answered all calls ahead of it.

For example, if the car has been travelling Up (81 operated) and calls exist below, on answering the highest call 81 will be released, thus preparing the circuit to 82 via *N/C* 81.

82 operates when *T*1 times out. The circuit to 82 is via the call relay contacts, the chain of *N/C* selector *S* contacts, *N/O* 23, *N/C* 81 and *N/C* *T*1. The function of *T*1 is to prevent sudden reversal of the car.

*N/O* 82 operates 87.

*N/O* 87 closes to hold 82.

Relay 83 is operated by *N/O* 81 for the Up direction and self-holds via its own *N/O* contact and *N/C* 82. 83 is released for the Down direction by the opening of *N/C* 82.

*C/O* 83 selects either *DMU* or *DMD* to step the selector for the correct direction.

### 3. Relay 13

Relay 13 is operated via winding *B–A*, *N/O* *FB*, *N/O* *T*2 and *N/O* 6*A* when the car is running.

When the car has stopped, relay 13 is timed out by *N/O* *T*2.

*N/O* 13 releases 80.

*N/C* 13 operates 20 to close the doors.

*N/C* 80 prepares the circuit to 43 via *N/O* 87 and *CGS* contacts.

*N/C* 80 prepares the circuit to 1 or 2.

Registration of a car call will cancel the time delay of 13. The operation of a car push operates relay *CP* so long as pressure is maintained on the push.

*N/O CP* energizes the neutralizing winding *C–D* of relay 13 via *N/C 6A* and *N/O* 13; and 13 releases.

The early release of 13 enables the car to start more quickly.

4. Door Operation

*Door Opening*. The car door and landing doors are connected by a solenoid-operated retractable vane. The solenoid which operates the vane is operated by relay 43.

*N/O* 47 releases 43 when the car stops.

*N/O* 43's open to release the retiring cam which ejects the vane to unlock the landing doors and to connect them with the car door.

The opening of the landing door lock contacts releases relay 41.

The opening of the doors is controlled by contactor 21.

When the car is approaching a floor at which it will stop, relay 80 operates.

*N/O* 80 operates 100 via *N/O* 26 and *N/O FB*.

100 holds via its own *N/O* contact, *N/O FB* and *N/O* 26.

*N/O* 100 operates 21 via *DGOL*'s, limit *ODL*, *N/C* 43, *N/C* 41, *N/C* 20 and *N/C* 47.

*N/O* 21's close to energize the door gear motor, and the doors commence to open. *CGS* contacts open.

*N/O* 21's operate *T*2.

*N/O T*2 operates 13 via winding *B–A* and *N/O* 100.

When the doors have fully opened, limit *ODL* opens to release 26 and contactor 21.

*N/O* 26 releases 100.

*N/O* 21's open to de-energize the door gear motor.

*N/O* 21's open to commence the timing out of *T*2.

The doors may be opened by pressure on the Open Doors push in the car. This push operates relay 100 which opens the doors as described above.

The doors may be opened at the floor at which the lift is standing by pressing the landing push at that floor. This operates the corresponding landing call relay, which selfholds.

Contacts of the call relay operate 80 via a *N/O G* contact and *N/C* 1.

*N/O* 80 operates 100 which opens the doors as described above. When the doors have fully opened, *N/O* 26 and *N/O* 61 or *N/O* 61*A* release the call relay.

*Door Closing.* The closing of the doors is controlled by contactor 20.

When relay 13 times out, *N/C* 13 operates 20 via *DGOL*'s, *N/O FD*, *N/O T5A*, *N/C* 100, *N/C* 21 and *N/C* 47. (See section 3.)

*N/O* 20's close to energize the door gear motor, and the doors commence to close. When the doors have fully closed, limit *CDL* opens to release 20.

*N/O* 20's open to de-energize the door gear motor.

The doors may be reopened during closing by pressure on the safety edges or by operation of the OPEN DOORS push.

Relay 100 operates.

*N/C* 100 opens to release 20.

*N/O* 20's open to de-energize the door gear motor to stop the doors.

*N/C* 20 with *N/O* 100 operate 21 to reopen the doors.

*Door Test Switches.* Switches are provided in the car to enable the doors to be tested under power. The TEST–RESET switch is placed in the TEST position to cut off the normal feed to 81 and 82, and to operate *MA* and *MAA*. *N/C MA* isolates the landing call relays and *N/C MAA* isolates the car call relays.

The doors may now be tested by operating the OPEN–CLOSE switch. Relay 100 is operated to open the doors and 87 is operated to close the doors.

With relays *MA* and *MAA* operated, the lift is on MAINTENANCE control and is operated from the UP and DOWN pushes on top of the car.

*Door Protection Timer.* When the doors commence to open, the limit *CDL* closes, thus making the supply to the *T*5 circuit.

*T*5 will operate and will remain operated during the normal door open-close cycle. When the doors are reclosed, limit *CDL* will break the circuit to *T*5. Under this condition *T*5 will remain operated.

If, for some reason, the doors do not fully close (e.g. the safety edge continually meeting with some obstruction) *T*5 will time out after the normal open-close time has elapsed.

*N/O T*5 will release *T5A*.

*N/O T5A* will open in the circuit to 20.

*N/C T5A* will maintain 20 via *N/O* 87.

The safety edges will again operate 100 to open the doors and release relay 26.

*N/O* contacts of 26 and *T5A* open to release the existing car calls and landing calls.

81 or 82 releases, and *N/O* 81 or *N/O* 82 releases 87.

When *T5* has timed out, an attempt may be made to close the doors by operating a landing push, or they may be closed by a car push.

The circuit to 20 is via *N/O* 87 and *N/C T5A*.

5. Power Section

*Starting.* Starting is initiated automatically by the release of relay 13 (see section 3) provided that calls exist in the system.

The sequence is shown for the Up direction.

*N/C* 13 operates 20 to close the doors, as described elsewhere.

81 and 87 will be operated.

*N/O* 87 operates *T9* and *T10*.

*N/O* 13 releases 80 (see end of this section).

*N/C* 80 prepares the circuit to 43 via *N/O* 87.

*N/C* 80 prepares the circuit to 1 via *N/O* 81, *N/C* 2 and limit *UL*.

When the doors have closed and locked, the lock contacts complete the circuit to 1, which operates.

1 selfholds via its own *N/O* contact, *N/C MAA*, *N/O FB* and *N/C* 80.

*N/O* 1 operates 47.

*N/O* 47's operate *T1*.

*N/O T1* operates *T2*.

*N/O* 47 maintains 43.

*N/O* 47 operates *6A* via *N/O T9* and *N/O T10*.

*N/O 6A* operates 6.

*N/O 6A* holds *6A* and 6.

*N/O* 1's and *N/O* 6's close to energize the main motor.

*N/O* 1 and *N/O* 6 close to lift the brake and the car starts with full resistance in circuit.

*N/O* 6 operates 48 and *48A*.

*Acceleration.* *N/C* 6's open to commence the timing out of *T9*.

*T9* times out and *N/C T9* operates 9 via *N/O* 6.

*N/O* 9's close to move the star point to *D2*, *E2*, *F2*, and the motor accelerates.

*N/C* 9's open to commence the timing out of *T*10.

*T*10 times out and *N/C T*10 operates 10 via *N/O* 6.

*N/O* 10's close to move the star point to *D*, *E*, *F*, and the motor accelerates to full speed.

*Stopping.* Stopping is initiated by the operation of relay 80.

Relay 80 operates to stop the car in answer to a car call, irrespective of the direction of travel. Assume that a car call for the 3rd floor has been registered:

When the lift enters the 3rd floor zone, relay 3*G* operates.

*N/O* 3*G* operates 80 via *N/O* 3*C* and *N/O* 13.

80 selfholds via its own *N/O* contact and *N/O* 13.

Relay *LS* operates as the car comes on to the *ZS* plate which precedes the 3rd floor (when 3*G* operates).

*N/O LS* holds across *N/C* 80 to maintain 1.

As the car comes off the *ZS* plate, relay *LS* releases and so releases 1.

*N/O* 1 releases 47.

*N/O* 47 releases 6.

*N/O* 1's and *N/O* 6's open to de-energize the motor.

*N/O* 1 and *N/O* 6 open to apply the brake which stops the car.

The car stops for landing calls when it is travelling in the DOWN direction only.

Relay 80 is operated by *N/O G* contacts via *N/O* contacts of the landing call relays and *N/C* 1.

The car will stop for a landing call when it is travelling UP provided there are no calls ahead of it. When this occurs, relay 80 is operated by *N/C* 81 via *N/O* 83 and *N/O* 13.

The car then reverses to answer the existing landing calls which were by-passed on the UP journey.

80 is released each time by the timing out of 13, in preparation for the next journey.

6. PARKING FEATURE

A parking call for the main floor is registered by the timing out of *T*2, each time the car answers the first call away from the main floor.

*N/C T*2 operates 1*C* via winding *B–A*, *N/O FD*, *N/O T*5*A* and *N/C* 1*G* contacts.

When there are no further calls to be answered, the car will start for the main floor, and when it arrives will park with doors closed.

Relay *1C* is cancelled by the opening of *N/O 6A* contact when the car stops.

7. Fire Service Switch

Relay *FC* is operated via the Fire Service switch.

*N/O FC* operates *FD*.

*N/O FC* operates *FB*.

*FD* holds via its own *N/O* contact and *N/C 1G*.

Placing the Fire Service switch in the Open position enables a person to gain control of the lift in an emergency.

Relay *FC* releases and *N/O FC* releases *FB*.

*N/O FC* contacts open to release existing car calls and landing calls.

Assume that the lift is standing at a floor and the doors are opening.

*N/O FB* opens to release 100.

*N/O FB* releases 13.

*N/O* 100 releases 21 to stop the doors.

*N/C* 100 with *N/C* 13 close to operate 20, which immediately closes the doors.

*N/C FC* operates *1C* to start the car for the main floor.

When the car enters the first-floor zone, *N/C 1G* releases *FD*.

*N/C FD* reoperates *FB*.

*N/O FD* opens to release *1C* and to prevent the registration of a parking call while the lift is on Fire Service.

*N/O FD* opens in the circuit to 20.

*N/O FB* reoperates 13 via *N/O T2*.

*N/O* 13 operates 80 via *N/C* 82 and *N/C* 1.

*N/O* 80 operates 100.

*N/O* 100 prepares 21 for opening the doors.

When the car stops the doors open (41 and 43 release).

The doors are prevented from closing automatically by the inclusion of *N/O FD* in series with *N/C* 13 in the 20 circuit.

*N/C FD* restores the feed to the car pushes via *N/O T5A*.

The lift is now completely under the control of a person in the car.

The registration of a car call will operate 81.

*N/O* 81 operates 87.

*N/O* 87 operates 20 via *N/O CP*, to close the doors.

*Note.* Constant pressure must be maintained on the car push until the doors have fully closed. Premature release of the

push will release 20 to stop the doors, due to the release of *CP*. When the car arrives at the required floor, it will remain there with the doors open until a further call is registered.

If the Fire Service switch is opened while the lift is travelling DOWN, it will proceed directly to the main floor.

Assume that the Fire Service switch is opened while the lift is travelling UP:

*N/O FB* opens to release 1.

*N/O* 1 releases 47.

*N/O* 47 releases 6.

*N/O* 1's and *N/O* 6's open to de-energize the motor.

*N/O* 1 and *N/O* 6 open to apply the brake, which stops the car.

Relay 1*C* is operated as described above.

When *T*1 times out, *N/C T*1 operates 82 to initiate starting for the DOWN direction.

If the Fire Service switch is opened while the lift is parked at the main floor with the doors closed, the doors open as follows—

*N/O FC* releases *FD* (*N/C* 1*G* is open in hold circuit).

*N/C FD* in series with *N/C* 87 operates 21 to open the doors. (The doors cannot be opened by a landing push because the pushes are isolated by *N/O FC*.)

If the Fire Service switch is opened during closing of the doors, the doors will continue to close.

*N/O* 20 maintains contactor 20 until the doors have fully closed.

The car will then proceed to the parking floor as described earlier.

*Note.* Chokes and condensers are fitted to various parts of the circuit to minimize interference to radio and television reception.

## Variable Voltage Dual Directional Collective Controller

The following description relates to a typical Waygood-Otis controller of this type, the circuit diagram of which is in Fig. 231. The motor generator set, lift motor, and gearing are shown in Fig. 232 and the controller in Fig. 233.

1. NAMES OF FIELD APPARATUS AND OPERATING EQUIPMENT

| | |
|---|---|
| *ADL* . . | Attendant Down Light |
| *ASC* . . | Auxiliary Stop Contacts |

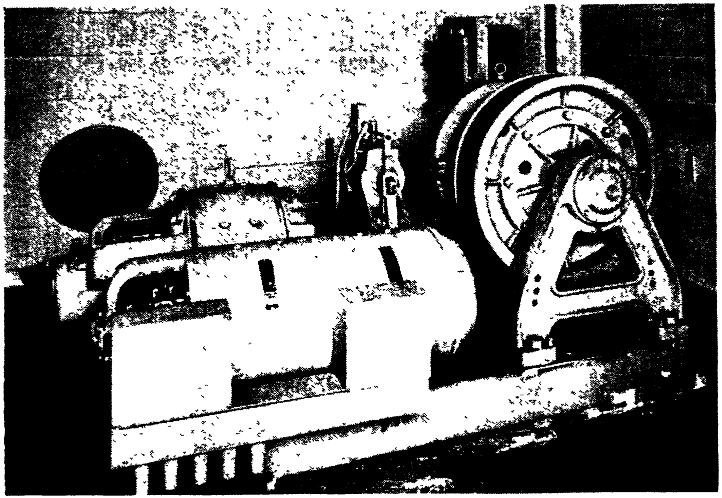


FIG. 232. VARIABLE VOLTAGE GEARED LIFT DRIVE
(*By courtesy of the Postmaster-General*)

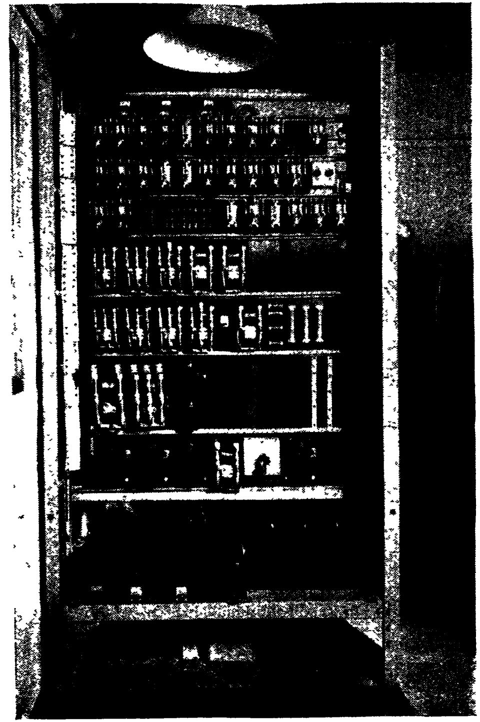


FIG. 233. VARIABLE VOLTAGE DUAL COLLECTIVE CONTROLLER
(*By courtesy of the Postmaster-General*)

| | |
|---|---|
| *ATS* . . | Attendant Cut-out Switch |
| *AUL* . . | Attendant Up Light |
| *B* . . | Brake |
| *BS* . . | Brake-operated Switch |
| *BU* . . | Buzzer |
| *BTS* . . | Broken-tape Switch |
| *CAC* . . | Car Contacts |
| *CAR* . . | Car Reset Brush |
| *CB* . . | Car Buttons |
| *CDDL* . | Down Car Direction Light |
| *CM* . . | Retiring Cam Magnet |
| *CUDL* . | Up Car Direction Light |
| *D* . . | Down Inspection Button |
| *DAS* . . | Down Auxiliary Stop Brush |
| *DCS* . . | Down Car Stop Brush |
| *DHC* . . | Down Hall Contacts |
| *DHR* . . | Down Hall Reset Brush |
| *DHS* . . | Down Hall Stop Brush |
| *DS* . . | Door Contacts |
| *DV* . . | M.G. Set Driving Motor |
| *EEC* . . | Emergency Exit Contact |
| *ES* . . | Emergency Stop Switch |
| *FDC* . . | Floor Directional Cam |
| *FH* . . | Floor Brush Switch |
| *GA* . . | Generator Armature |
| *GIP* . . | Generator Interpole Field |
| *GLF* . . | Generator Levelling Field |
| *GS* . . | Gate Contact |
| *GSEF* . . | Generator Self-excited Field |
| *GSF* . . | Generator Series Field |
| *GSH* . . | Generator Series Field Shunt |
| *GW* . . | Gate Contact Switch |
| *HB* . . | Hall Buttons |
| *HDDL* . | Down Hall Direction Light |
| *HPI* . . | Hall Position Indicator |
| *HUDL* . | Up Hall Direction Light |
| *INS* . . | Inspection Knife Switch |
| *KS* . . | Knife Switch |
| *1LS* . . | Down Final Limit Switch |
| *2LS* . . | Up Final Limit Switch |

| | |
|---|---|
| *LV* . | . Levelling Switch |
| *MA* . | . Elevator Motor Armature |
| *MCB* . | . Main Circuit Breaker |
| *MF* . | . Elevator Motor Shunt Field |
| *MIP* . | . Elevator Motor Interpole Field |
| *NSB* . | . Non-Stop Button |
| *OS* . | . Governor Overspeed Switch |
| *PLT* . | . Pilot Light |
| *IRF*, etc. | . Rectifiers |
| *SES* . | . Service Emergency Stop Switch |
| *SKS*1 . | . Service Knife Switch (Motor) |
| *SKS*2 . | . Service Knife Switch (Controller) |
| *SOS* . | . Safety-operated Switch |
| *SS* . | . Car-stopping Switch |
| *SSK* . | . Signal Cut-out Knife Switch |
| *TKS* . | . Test Button Knife Switch |
| *TRF* . | . Rectifier Transformer |
| *TRS* . | . Signal Transformer |
| *U* . | . Up Inspection Button |
| *UAS* . | . Up Auxiliary Stop Brush |
| *UCS* . | . Up Car Stop Brush |
| *UHC* . | . Up Hall Contacts |
| *UHR* . | . Up Hall Reset Brush |
| *UHS* . | . Up Hall Stop Brush |

2. Names of Switches and Relays on Controller and Relay Panel

| | |
|---|---|
| 1*AE* . | . 1st Attendant Switch |
| 2*AE* . | . 2nd Attendant Switch |
| *ATC* . | . Attendant Control Relay |
| *ATD* . | . Down Attendant Switch |
| *ATU* . | . Up Attendant Switch |
| *BL* . | . Buzzer Switch |
| *C* . | . Potential Switch |
| 1*C*-*TC* | . Car-stop Floor Relays |
| *D* . | . Down Direction Switch |
| 2*D*–*TD* | . Down Floor Relays |
| *DF* . | . Direction Field Relay |
| *DTB* . | . Down Test Button |
| *DX* . | . Down Auxiliary Direction Switch |

| | |
|---|---|
| *ER* . | . Excitation Switch |
| *ERT* . | . Excitation Time Switch |
| 1*E* . | . 1st Slow-speed Switch |
| 2*E* . | . 2nd Slow-speed Switch |
| 3*E* . | . 3rd Slow-speed Switch |
| *GL* . | . Levelling Slow-speed Switch |
| *H* . | . Field and Brake Switch |
| *HX* . | . Auxiliary Field and Brake Switch |
| *J* . | . Reverse Phase Relay |
| *K* . | . Starting Switch |
| *KR* . | . Running Switch |
| *LD* . | . Down Light Switch |
| *LE* . | . Levelling Fast-speed Switch |
| *LU* . | . Up Light Switch |
| *MC* . | . Minimum-current Shunt Field Relay |
| *NT* . | . Hall Time Switch |
| 1*P*, 2*P*, 3*P*, and 4*P* | . Overload Switches |
| *Q* . | . Load Switch |
| *S* . | . Starting Switch |
| *SF* . | . Series Field Switch |
| *ST* . | . Stopping Switch |
| *STX* . | . Auxiliary Stopping Switch |
| *SUD* . | . Suicide Delay Switch |
| *TS* . | . Double-journey Relay |
| *U* . | . Up Direction Switch |
| 1*U*, etc. | . Up Floor Relays |
| *UTB* . | . Up Test Button |
| *UX* . | . Up Auxiliary Direction Switch |
| *VR* . | . Voltage Relay |
| *XD* . | . Down-direction Switch Relay |
| *XKR* . | . Running Switch Relay |
| *XQ* . | . Load Switch Relay |
| *XU* . | . Up-direction Switch Relay |

3. Sequence of Operation

Assume that—

Attendant switch *ATC* is closed to "Auto."

Main circuit breaker *MCB* and Service Knife Switches *SKS*1 and 2 are closed.

Transformer *TRF* and rectifier 1*RF* are energized. Rectifier 1*RF* supplies continuous d.c. power to operating circuit terminals *C*14 to *HL*1.

Reverse Phase Relay *J* is energized and its contact closed.

Car is parked at the bottom landing with doors closed.

Motor Generator is shut down.

All mechanical switches are in their normal position as shown on diagram.

An intending passenger wishes to travel from the bottom landing to the third landing.

*Car Call Operation and Starting Motor Generator*

1. Passenger opens landing and car doors, enters car and registers a third-landing call by pressing the appropriate car button. Assume that a top floor down hall call is also registered. Switches *LU* and *XU* pull in.

2. Switches *ERT*, *ER* and *K* pull in.

Rectifier 2*RF* is energized to supply d.c. power to the main operating circuit terminals *MF* and *HL*1.

3. M.G. driving motor *DV* starts up on star connexion and generator armature *GA* comes up to speed.

4. Shunt field *MF* builds up to minimum standing value and relay *MC* pulls in.

5. Switch *XKR* pulls in and switch *K* drops out after a slight time delay.

Switches *KR* and *C* pull in.

M.G. driving motor *DV* transfer from star to delta connexion.

6. Meanwhile, the doors have been closed and gate contact switch *GW* pulls in. Contacts *ADS* and *GS* are closed.

7. Switch *NT* drops out after a time delay and switch *S* pulls in.

8. Coil *LV* is energized to lift the contacts off the cam, and contacts *LV*2 and *LV*6 make.

9. Coil *CM* is energized to retire the lock cam. Contacts *DS* are closed.

10. Switches *UX*, *U* and *H* pull in.

Switches *HX*, *SUD* and *SF* pull in.

Generator levelling field *GLF* builds up, and switch *DF* pulls in.

Motor field *MF* builds up to full strength.

Brake $B$ lifts.

Motor armature $MA$ starts to turn and car starts moving up.

11. Switches $1E$, $2E$, $3E$, and $GL$ pull in.

Switch $SF$ drops out.

Generator field $GSEF$ is connected across the generator and starts building up.

Switch $VR$ pulls in.

Generator armature $GA$ voltage builds up to rated value and armature $MA$ accelerates up to speed.

Car runs full contract speed up.

Slow-down and Stopping

12. Crosshead panel contact $UCS$ touches third-floor bar contact $CAC$, and switch $ST$ pulls in.

At the same time crosshead contact $UAS$ touches third-floor bar contact $ASC$.

Switch $STX$ pulls in.

Switch $ST$ drops out, and floor relay $3C$ resets.

13. Crosshead contact $UAS$ rides off bar contact $ASC$, and switches $S$ and $STX$ drop out.

14. Levelling switch $LV$ releases.

Switch $1E$ drops out, and switch $2E$ starts drop-out timing.

Resistance $GF1$ is inserted in series with generator field $GSEF$, and the car slows down first stop.

15. Switch $2E$ drops out to insert series resistance $GF2$ and shunt resistance $GF5$ in generator field $GSEF$.

Car slows down second stop.

16. Levelling switch contacts No. 1, No. 3, and No. 4 are bridged together by levelling cam, and switch $LE$ pulls in.

17. Levelling contact $LV2$ breaks.

Switches $UX$ and $HX$ drop out.

Switch $3E$ drops out and switch $SF$ pulls in.

Resistance $GF5$ is reduced and field $GSEF$ is disconnected.

Switch $NT$ starts drop-out timing.

Car slows down to fast-speed levelling speed.

18. Coil $CM$ is de-energized, lock cam advances and contacts $DS$ open.

19. Levelling switch cam rides off contact $LV4$, and switch $LE$ drops out.

Switch $GL$ starts drop-out timing.

Car slows down to slow-speed levelling speed.

20. Levelling switch cam rides off contact *LV*3, and switches *U* and *H* drop out.

Switch *GL* drops out, and switch *SUD* follows after slight time delay.

Switch *SF* drops out.

Brake sets and car comes to a stop at second floor.

21. Passenger opens doors, leaves car and recloses doors.

*Hall Call Operation*

22. Top floor hall call *TD* is registered and set.

Switches *LU* and *XU* remain in.

23. Switch *NT* drops out.

24. Switch *S* pulls in.

Coil *LV* is energized to lift levelling contacts off cam.

25. Steps 9 to 11 are now repeated.

Slow-down and Stopping

26. Spring contact (*FH* 1–2) on top-floor bar breaks.

Switches *LU* and *XU* drop out.

27. Crosshead contact *UAS* touches top-floor bar contact *ASC*, and switch *STX* pulls in.

28. Steps 13 through 18 now follow in order.

29. Steps 19 through 21 now follow in order.

4. Notes on Special Switches and Relays

1. Load relay *XQ* and load switch *Q* operate to compensate for loss of speed due to load.

2. Voltage relay *VR* is set to operate at about 50 per cent armature voltage to insure that *XQ* operates at a specified load only.

3. Switch *GL* drops out with switch *H* to boost car back to the floor on a relevel operation. It also boosts car into floor when lifting load, and pulls the car out of a stall if necessary.

4. Relay *DF* must operate for fast-speed operation. Main field *GF* cannot be connected across armature *GA* without first setting up direction field.

5. On attendant operation, switches 1*AE* and 2*AE* operate to make operation subject to attendant.

They also permit operator to select direction of operation.

6. Switches *ATU* and *ATD* operate for up and down operation on both attendant and inspection operation.

Car operates at slow speed only when on inspection operation.

## Variable Voltage Electronic Controller

The method of obtaining a variable voltage for controlling the speed of a d.c. motor from a grid-controlled mercury arc rectifier is described in Chapter VI in which there is a front view of the controller. A rear view of the same controller is shown in Fig. 234. A typical diagram of a four-floor automatic lift incorporating a mercury arc rectifier with direct electronic control of the d.c. output voltage by the phase of the grid voltage is shown in Fig. 235. In this diagram an electro-magnetic phase shifter is used. The rotary resistance for controlling the speed can be coupled by magnetic clutches marked Accel or Decel to the chain drive from the lift, to accelerate or decelerate. By suitable grading of this rotary resistance any speed change curve may be attained. With neither clutch energized a weight ensures return of the camshaft to the starting position and, as a further precaution, the reverser circuit is interlocked by an auxiliary contact operated from the shaft. Other contacts on the shaft operate clutch economy resistances and connect a dynamic braking resistance across the lift motor armature.

Fig. 234
Rear View of Controller
*(Wm. Wadsworth & Sons)*

When the doors are closed the operation of a floor button energizes the appropriate Up or Down reverser and in turn the Speed relay and Accel clutch magnet so that the lift starts and by operating its own speed control accelerates to full speed. At the fast position the clutch slips under light load. The

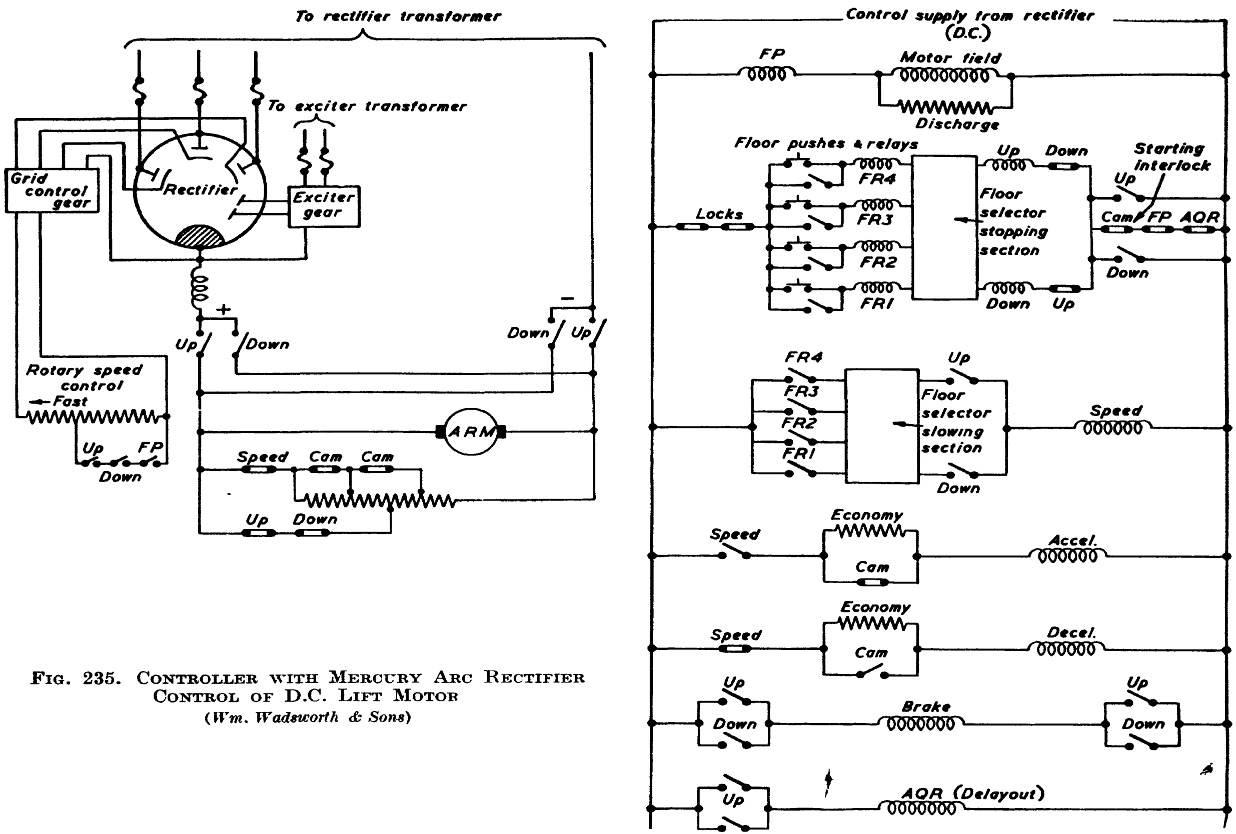



Fig. 235. Controller with Mercury Arc Rectifier Control of D.C. Lift Motor
(Wm. Wadsworth & Sons)

slowing section of the floor selector breaks the appropriate slowing contact at the proper distances from the floor. This releases the speed relay, a contact of which operates the DECEL clutch which restores the rectifier voltage to that needed for slow speed. It will be noted that the speed is related to distance in the well, and it is possible to obtain speed variation of 18 to 1 whilst maintaining a stable levelling speed. On arrival at the floor the stopping section of the floor selector interrupts the reverser circuit, applies the brake and stops the lift. Relay *AQR* is the usual anti-quick reversal relay to prevent the quick reversal of the motor. Contacts *CAM* are operated by the camshaft whilst *FR*1–4 are the floor relays. *FP* is the field under current protective relay.

# CHAPTER XVI

## MAINTENANCE AND TESTING

It is essential that a lift should receive proper periodical maintenance in order to obtain good service and to prevent the possibility of accidents to passengers. The inspections and tests should be performed by a qualified engineer, thoroughly acquainted with the mechanical and electrical details of the lift he is called upon to maintain. It is not sufficient to leave a lift in the hands of the "electrician," who is probably more acquainted with renewing fuses and removing faults from lighting and power circuits. If the services of a qualified lift mechanic are not available, it is recommended that the periodical maintenance be undertaken by a firm of lift engineers, preferably the makers of the lift. Almost all the reputable lift manufacturers have schemes whereby they carry out periodical inspections on lifts, for a comparatively small charge, and after each inspection submit to the owner a complete test report showing the condition of the lift. In fact, most firms would prefer this method of maintaining their own lift. Usually these standard inspections are carried out each month, during which time any necessary oiling is performed, adjustments made and, in addition, recommendations are made regarding any item of equipment, such as ropes, which require renewal. By this means the owner is informed of the condition of his lift or lifts every month and he is thus given an opportunity of remedying any defects before damage is done to the equipment or accidents occur to passengers.

The methods adopted by lift engineers for detecting faults, and the order of procedure in carrying out these tests vary, but the main items requiring inspection and means of curing troubles will be discussed.* It is, of course, not necessary to perform all the tests detailed below during each visit. To carry out a thorough inspection the mechanic must have the assistance of a mate.

* See *Lift Maintenance Manual*, issued by Messrs. Marryat & Scott.

(1) INSPECTIONS MADE IN THE MACHINE ROOM

**Switches and Fuses.** The motor room is probably the best and most usual place in which to commence an inspection, and before any testing of electrical parts is done the main switches for both motor and control circuits should be switched off. Although an electric shock from a low voltage may not normally be dangerous, it may cause one to jump suddenly and come in contact with a moving part of the equipment which might result in serious consequences. The size of the motor fuses and the setting of any circuit-breakers should be checked against the nameplate rating of the motor. The carrying currents of the motor fuses will vary from twice to five times full load, depending upon the type of motor. The control circuit current will generally not exceed about five amperes.

**Platform.** Examine the platform over the well to ensure that it is strong and rigid and securely fastened.

**Motor.** On examining the motor it will be noted that the end of the shaft is squared, the object being to allow of the insertion of a winding handle so that the car may be moved, in cases of emergency, or after overrunning a terminal landing and operating the final limit switch. Before the motor can be turned by hand, however, it is necessary to release the brake. This is done either by turning the brake hand release lever which is fitted to some brakes, or by wedging the shoes apart with a piece of wood. If the need for using the winding handle arises, care must be taken afterwards to remove the handle and either reset the brake hand release or remove the wooden wedge. On some lifts an interlocking contact is fitted to the brake hand release which, by disconnecting the control circuit, prevents the restarting of the lift until the release has been returned to its normal position. The commutator or slip-rings and brushes should be examined to make sure that the latter are making good contact, and are renewed before undue wear takes place. If plain bearings with ring lubricator are fitted, it should be noted whether the oil is at the correct level and whether any leakage is occurring at the drain plug, tap, or oil gauge. Ball or roller bearings are packed with grease by the makers, and replenishment is only necessary about every six months, when a little pure petroleum jelly should be used. Excessive wear of the bearings can often be detected by a distinct knock,

and results in undue strain being placed on the coupling and the worm gear bearings.

**Brake.** The next items are the brake and the coupling upon which the brake usually operates. The coupling should be examined to ensure that the bolts are tight and that the keys joining the shafts on each side are not loose. If the motor winding handle is inserted, and turned in each direction, looseness of the key on the motor shaft can be detected. Similarly, the key on the worm shaft may be observed, but in this case the brake must be released. Particular attention should be given to the adjustment of the brake, as an incorrectly adjusted brake will cause faulty floor levelling. When the design permits, each half should be adjusted independently so that the clearance of each shoe is the same. The clearance between the brake linings should be as small as possible, and will be found in practice to be between $\frac{1}{100}$ in. and $\frac{1}{64}$ in., if correctly adjusted. Next adjust the solenoid plunger so that the maximum possible pull is obtained. This is the case when the reluctance of the magnetic circuit is as small as possible and the maximum number of lines of force is present in the air gap. Under these conditions the brake should just operate when the magnetic circuit closes. The spring pressure should then be adjusted until smooth and rapid stopping are obtained; the actual stopping distance will vary with the car speed. After the brake has set, the car travel should not exceed about four inches for each 100 ft. per min. of running speed. The operation of any emergency brake gear should also be examined.

**Gearing.** The gearing is adjacent to the brake and will probably suggest itself as the next item for inspection. Examine the level of the oil in the gearbox which, if the gear is of the under-type, should be sufficiently high just to cover the worm. If the over-type gear is employed, the level should be about four inches above the bottom of the worm-wheel. The gear oil recommended by the makers should be used, but if this is not available, pure castor oil may be substituted. As in the case of all gearing, however, the mixing of oils in the gearcase is not recommended. The oil should be free from metal particles and should not be semi-solid, gummy or have an offensive odour. When vegetable oils become rancid most of the lubricating qualities have been lost. The gearcase should be examined for

leaks and tightened where necessary, and if the gland is showing signs of leakage, the gland nuts should be tightened up in rotation. Wear of the gear teeth can be detected by removing the gearbox cover and turning the motor by hand. Another method of detecting wear entails loading the car until the lift is balanced, and then, by overbalancing one side, a movement of the worm-wheel will indicate excessive wear of the teeth. The fixing of the worm-wheel rim to its centre should be carefully examined. A double thrust race is usually fitted at the outer end of the worm shaft to accommodate the worm thrust in both directions of travel, and an inspection of this thrust race is necessary to ensure that excessive wear has not taken place. If undue wear is present, the thrust is likely to be transferred to the motor bearings, which may overheat and cause a breakdown. Wear may be compensated for by removing the thrust and making adjustment.

**Sheaves and Pulleys.** An examination may next be made of the sheave or drum and any diverting pulleys to detect whether any looseness on the shafts is present due to keys working loose. Play may be detected by observing the line of contact of the sheave and its shaft when the lift starts or stops, and the "bubbling" of a little oil placed around the line of contact will clearly show any relative movement between the sheave or drum and the shaft. If looseness is present, the key should be driven in tightly, but it may be necessary to fit a new key. With a traction drive, the sheave grooves should be examined for wear, and if ridges are present in the grooves these may, in time, cause rope slip which will result in rope wear. Rope slip may be detected by chalking the rope and sheave, and after the lift has made a few journeys, again examining the marks, which should still coincide. The sheave should be examined carefully to ensure that all ropes seat to the same depth in the grooves. In addition to worn grooves, excessive use of lubricant on the ropes may be responsible for rope slip. In the former case the remedy is removing the sheave and having the grooves re-cut, whilst in the latter, removal of the excessive oil with a paraffined rag will cure the trouble. If the ropes "bottom" in the grooves, slip may again result and it is then necessary to fit larger ropes. If there is any doubt as to whether the traction is adequate a contract load test should be made. It should also

be noted whether the ropes lead on and off the sheave without binding on the sides of the grooves. The presence of a crack in the sheave, drum, or diverting pulleys may be detected by hammer testing. Test the bearing bolts for tightness.

**Controller.** The controller may now be inspected, and in carrying this out more good will probably result from a very careful visual inspection than anything else that may be done. Loose, disconnected, or short-circuited wires are frequent sources of trouble, whilst if stranded wire is used on any contactors, this should be examined for broken strands which may cause a breakdown in the near future. Badly burned contacts should be cleaned and if necessary adjusted. The contacts are copper-to-carbon or copper-to-copper, and in the latter case, if cleaning is necessary, care must be taken to ensure that any "roll" incorporated in the design is not reduced or destroyed. If this is done, welding of the contactors may result. When an appreciable amount of cleaning or filing of contacts is necessary, the profile of the contacts should be tested with a template having the same curvature as a new contact, before the contacts are replaced. The mechanical interlock between the reversing contactors should be examined if such an interlock is fitted. The pins on which the various contactors operate should be perfectly free and should occasionally be given a drop of thin oil. Careful inspection of any controller dashpots is necessary to ensure that they provide the time lags intended. It is important to use only the type of dashpot oil recommended by the makers, or the settings will become inaccurate. An electrical insulation test should be taken on motor and control circuits at a voltage of 500 volts d.c. and when taken from the main switch with all coils in circuit should not be less than 1MΩ.

**Floor Selector.** Now that the brake has been correctly adjusted, an inspection may be made of the floor selector gear if the lift is automatically controlled, and any necessary adjustments made. The operation of each striker arm and its associated switch should be examined to see whether the best possible levelling is obtained at each floor. Commencing with the up direction switch contacts, the lift should be called up from the bottom floor to the next floor, with no load in the car. The lift should level slightly high, say $\frac{3}{4}$ in. After measuring this distance, call the car up to the next floor and take a similar

measurement of the distance that the lift stops above this floor. After this has been done, repeat the tests, but with full load in the car, and in these cases the lift should stop a small distance below each floor. If necessary, the striker arms on the selector should be adjusted so that the stopping distances above the floors, when light, and the stopping distances below the floors, when carrying full load, are all equal. This adjustment will provide the best average levelling in the up direction for all loads if the counterweight is equal to the weight of the car plus 50 per cent full load. Hence, with 50 per cent full load, accurate levelling in the up direction should be obtained. If, however, the counterweight is, say, equal to car plus 40 per cent full load, it will be necessary for the car load during the load levelling test to be equal to 80 per cent full load instead of full load. This will ensure that correct levelling is obtained in the up direction with 40 per cent full load in the car. The strikers operating the down direction switches must be adjusted in a similar manner to that for the up switches, but with the car travelling in the down direction. During these down direction tests it will be noted that the empty car will again level high and the loaded car low. When a two-speed motor is employed, the floor selector will have slowing switches fitted for each direction in addition to stopping switches. The slowing switch strikers should be adjusted so that the lift speed is reduced to the low-speed value before the stopping switches are operated and the brake applied.

If stopping and levelling are performed by direction switches in the well and a cam is fitted on the car (see Chapter XIII), instead of a floor selector in the motor room, it will be necessary, in order to check the levelling, to take measurements at the floors after stopping the lift at each floor when travelling up empty. Adjustments should be made to the positions of the switches (except the ground floor switch) so that the stopping distances above each floor are equal. Similarly, the position of the ground floor switch should be adjusted until the stopping distances below each floor are equal when the car travels down loaded. If the actual distance in the well between the up and down stopping points at each landing is now made equal to say, $1\frac{1}{2}$ in., i.e. $\frac{3}{4}$ in. above the landing and $\frac{3}{4}$ in. below the landing, then levelling to within $\frac{3}{4}$ in. will be obtained. For

example, if the up empty levels were all $1\frac{1}{2}$ in. high, and the down loaded levels all $\frac{1}{2}$ in. low, the top horn on the cam must be raised by $\frac{3}{4}$ in. and the bottom horn raised $\frac{1}{4}$ in. When the switches and cam have been adjusted, the only reason for inaccurate floor levelling will be that the brake is out of adjustment. It will probably be found more convenient to test these direction switches, when fitted, after the motor room inspection has been completed.

**Final Terminal Stopping Switch.** This should be occasionally tested by holding in the appropriate controller contactors and allowing the car to operate the switch after over-travelling each terminal landing in turn. The final limit switch is usually operated by a striker on the car engaging with a stop on the limit switch operating rope, one stop being fitted for each terminal landing. The overrun, after passing the terminal floor and before the limit switch operates, may be adjusted by altering the position of the rope stop. Two paint marks on the operating rope or pieces of adhesive tape are often used to indicate that, when the marks are opposite each other, the rope stops are in their correct positions in the well.

**Governor.** The overspeed governor must be lubricated where necessary and kept clean. During inspection the weights should be operated by hand to see that, firstly, the control cut-off switch operates, and secondly, the governor gripping jaws are released and grip the governor rope.

**Motor Generator Set and Compressor.** With variable voltage equipment, an inspection of the motor generator set is necessary, and if pneumatic door operating gear is installed, attention should be given to the air compressing plant, which will probably be located in the motor room.

**Ropes.** Before leaving the motor room, a careful visual examination should be made of those portions of the lifting ropes which pass over the sheave or drum during a complete journey of the lift. Any "needling" of the ropes, i.e. broken wires, should be carefully noted; the detection of these "needles" being greatly facilitated by the aid of a small mirror used for the underside of the ropes or by a wad of cotton waste held lightly against the ropes. If preformed ropes are used, much greater care will be necessary in detecting broken wires as they retain their original positions in the strands even when

fractured. The presence of a few broken wires does not indicate that the rope should be immediately renewed, as the factor of safety is usually about 10, but rather that the ropes should be kept under careful observation during subsequent visits. It is very difficult to quote any rule for determining when ropes should be renewed as cases have occurred of ropes failing when no broken wires have been visible, and others when the rope has given long service after a comparatively large number of wires have been broken. The decision to renew a rope rests largely upon the engineer's experience and is usually governed by the number of adjacent broken wires. Undue rope stretch is another indication of approaching rope failure.

When rope renewal is considered necessary, careful measurements must be made to ascertain the length and size of rope required. Due allowance must be made for wear and stretch of the old ropes in determining the correct rope size, and usually the measured diameter of the old ropes will lie between two standard sizes. The larger of the two sizes will invariably be the correct size of rope required, the specified size being that of the circumference of the circumscribed circle. Rope fastenings are made either by sockets, splicing, or the use of bulldog grips, and in some circumstances it may be preferable for the splices to be made before the rope is delivered, whilst in others these could more conveniently be made during fixing, providing a qualified splicer is available. During re-roping, care must be taken to bind the ends of the ropes before cutting (unless preformed ropes are used) to prevent unravelling. The actual method adopted for re-roping will depend upon the type of lift and other local conditions, but it is usually possible to position the car at the top landing so that the car top is accessible from that landing, and the bottom accessible from the landing below. When in this position, the counterweight is supported by a wooden prop in the well bottom. The car is next raised a few inches by means of lifting tackle and a sling around the car crosshead and all is in readiness for removal of the old ropes and fixing of the new ones. The worn ropes may conveniently be used for towing the new ropes into position by temporarily fixing the former to the latter. Oil should not be used on the lifting ropes unless the lift is in a damp location, when a little may be applied to prevent rusting of the ropes.

### (2) INSPECTIONS MADE FROM THE LANDINGS

**Well Enclosure.** If the well is of the open type, examine the enclosure at all floors to ascertain that it extends from floor to floor and, if mesh screens are used, that they are of the required mesh and are properly fastened.

**Call Buttons.** Call the car to each landing by pressing the landing buttons in turn and if the lift is arranged for dual control and the inspector's mate rides in the car during these tests, the operation of the car call indicator and position indicator can be observed at the same time.

**Landing Indicators.** These can be inspected for satisfactory working when the landing buttons are tested.

**Landing Gates or Doors.** The lock of each landing gate or door should be tested by ascertaining that it is impossible to open any gate or door by pulling or lifting, or to stop the lift by breaking the electric interlock circuit, unless the car is at that landing.

It should also not be possible to move the car away from any landing with the gate or door at that landing open and if this is confirmed at each landing, then the landing door electric interlocks are breaking contact satisfactorily.

If gates are fitted, it is now a convenient time to note whether they can be opened or closed readily and if not, a drop of oil on each picket pin and on the overhead supporting roller pins, unless the latter are of the ball bearing type, will ensure easy operation. See that door hangers and tracks are clear and adequately lubricated.

**Retiring Cam.** This can be tested by maintaining a steady opening pressure on each landing door in turn in an endeavour to open it as the car passes the particular landing. It should, of course, be impossible to "snatch" open the door in this manner when the car is passing.

**Landing Gate or Door Emergency Key.** If this facility is provided, ascertain that the key is available to the maintenance engineer and that it will enable any landing gate or door to be opened for inspection or emergency purposes irrespective of the position of the car.

### (3) INSPECTIONS MADE FROM INSIDE THE CAR

**Car Floor Switch.** Some passenger lifts have a switch fitted

under the car floor, the switch being operated by pressure on the movable floor of the car. This switch is wired in parallel with the car gate or door contact and when the floor is in the UP position, i.e. no passengers in the car, the floor switch contacts are made. Hence it is possible for the empty car to be called to another landing with the car gate or door open. When a passenger enters the car, however, the floor switch contacts are opened and the car gate or door contact is then operative, and the gate must now be closed before the lift can be moved. It will be seen from the above that if the switch fails to open with the weight of a passenger on the floor, a dangerous condition will result, as the occupied lift can then be moved with the car gate or door open. For this reason these switches are not fitted on new lifts, and in fact their use is prohibited in the "Code of Practice for Lifts," which states that the car door or gate electric switch shall prevent the lift from being started or kept in motion unless the car gates or doors are closed.

Nevertheless, many of these switches still exist and the need for their thorough and periodical maintenance will be clear from what is stated above. The floor must be absolutely free in action and should be raised at every maintenance visit, all dust and dirt cleaned out and the hinges and spindles lubricated.

**Car Door or Gate Electric Contact.** If this switch closes and opens satisfactorily the car may be moved by the car buttons or car switch if the door is closed but it cannot be moved if the door is open. The cover of the switch should be removed occasionally and if necessary the spindles lightly oiled and the contacts cleaned. The position of this interlock may be such, however, that it may have to be inspected from the top of the car.

**Car Switch.** It is easy to test the operation of this switch by moving the car up and down and at the various car speeds as indicated on the switch plate. The cover may be taken off, the inside of the switch carefully wiped, working parts lightly oiled, and the contacts cleaned.

**Car Push Buttons.** Test these by bringing the car to each floor in turn by pressing the appropriate button. It should be possible to stop the motion of the car at any position in the well by operating the stop button. If any button is uncertain in its

action the cover plate should be removed and the contacts cleaned and if necessary a new spring fitted.

**Car Safety Gear.** If of the wedge clamp type the removable panel in the floor should be raised and that portion of the drum and safety rope which is visible should be inspected, cleaned, and oiled where necessary.

**Emergency Exit.** Open the exit to ascertain that, if at the top of the car, it opens outwards and if at the side, inwards. If a top exit, it should be capable of being opened from inside or outside the car and when open should clear any equipment mounted on the top of the car. Where an electric interlock is provided it should be impossible to start the car with the exit open.

**Emergency Signal.** The bell, buzzer or telephone fitted in the car should be operated and should be clearly audible outside the lift well when the car is midway between adjacent landings. In large buildings this signal may be arranged to give a warning in the maintenance engineer's room.

**Lighting Fitting.** Examine to see that it is securely fastened, that the illumination is adequate, and that the switch operates satisfactorily.

**Travelling Conditions.** Run the car up and down the well and observe the action of the brake when stopping. The slide of the car should not be excessive nor should the stop be too abrupt. The acceleration and retardation should be noted to find out whether starting and stopping are smooth and reasonably rapid.

### (4) INSPECTIONS MADE FROM THE TOP OF THE CAR

To get on top of the car, the crosshead should be brought approximately level with a landing, either by lowering the car with the winding handle, after switching off and releasing the brake, or by operating the car stop button. In either case a mate is necessary in the car. Then by using the landing gate emergency key or otherwise circumventing the landing lock safety feature, which method should be known to the lift maintenance engineer, the gate may be opened to give access to the car top. The inspector should stand on the car crosshead near the rope fastenings and hold the lifting ropes firmly with one hand when the car is in motion. When in this position it

is better, if possible, to arrange for the car to travel in the down direction.

**Door Operating Gear.** Examine the motor and door operating levers, clean and lubricate if necessary. Watch the operation of the gear when the doors open and close.

**Retiring Cam Mechanism.** Operate the cam by pulling the connecting chain by hand and note if the cam advances and retires freely. Observe whether it clears the door lock striker arm or the sill trip lever when in the retired position. The operating solenoid or motor and levers should be examined and lubricated.

**Governor Rope Release Carrier.** Visually examine the rope grip and the springs to see that they are clean and not rusted. This release should be tested by engaging the governor jaws (usually in the machine room) with the governor rope by hand and then lowering the car either by the motor hand wheel or at the slow levelling speed. The shackle should then pull out of its carrier and if the descent of the car is not checked the safety gear will operate.

**Car Shoes and Guide Lubricators.** Inspect the top pair of shoes for wear of the linings and see that the housings are securely fixed to the car frame. If the shoes are spring loaded the springs may be tested by rocking the car to and fro sideways. Excessive side play may be cured with most types of shoes by fitting a steel washer between the back of the shoe and its housing. Examine the guide lubricators to ensure that the feed wicks are properly adjusted and that the reservoirs are filled with oil.

**Multiplying Pulley.** If the roping is 2 to 1 inspect the multiplying pulley for cracks and for adequate lubrication.

**Ropes.** By moving the car until the top is level with the top of the counterweight the lifting ropes and their fastenings at the car and counterweight may be inspected. Examine the ropes carefully for "needling" and for any irregular shape which may be due to a strand pulling out and carrying no load, this being caused by faulty splicing. If bulldog grips are used see that a sufficient number is employed and that they are fitted in the correct manner. Any rope equalizing gear may now be inspected and lubricated and the position of the levers noted, particular care being taken to see if a rope has stretched

sufficiently to cause the gear to wedge in one of the extreme positions of its movement.

If the car is moved slowly from the top of the well to the bottom, during which it is stopped at intervals of about 5 feet, the lifting ropes above the counterweight may be examined for broken wires, dryness and rust, or excessive lubricant. If dry and showing signs of rust, they should be lightly lubricated, but this should not be overdone or the result, with a traction drive, will be rope slip. At the same time the compensating ropes, governor rope and the final terminal stopping switch rope, tape or wire may be inspected in a similar manner.

**Rope Tensions.** If rope equalizing gear is not fitted, the rope tensions may be tested with the car about half way between the top of the well and the counterweight. Pull each rope in turn with a spring balance and note the deflections with equal pulls. If any rope can be deflected more than the others it is not carrying its proper share of the load and adjustment should be made at its screwed support.

**Counterweight.** When the car is opposite the counterweight, the counterweight shoes and guide lubricators may be inspected in a similar manner to that adopted for the car fittings. Examine the counterweight sections to see that none is displaced in the frame and that the nuts and pins are in their proper positions at the ends of the tie rods. If 2 to 1 roping is employed see that the pulley at the top of the counterweight is adequately lubricated. In many lifts the counterweight oil buffers are fitted to the bottom of the counterweight and if this is the case examine the oil level in them. Make sure that the counterweight guard at the mid-well position is securely fixed. Inspect the counterweight safety gear as described later for the car gear.

**Guides.** When moving the car slowly from the top to the bottom of the well, the guide surfaces, joints, clips and brackets should be inspected for wear or looseness and when the car is at the bottom landing any noticeable bend in the guides can be detected by sighting along the face of each car and counterweight guide in turn.

**Landing Gate or Door Locks.** These should be examined periodically and if necessary the striker arms adjusted and worn rubbers renewed. The covers should be removed, the

inside of the box wiped free of dust, the mechanism lightly oiled and the contacts cleaned. With centre opening swing doors the locks are mounted on the underside of the door top frame and these may be inspected from the landing or the inside of the car.

**Slowing and Stopping Switches.** If slowing and stopping are performed by switches on the car and cams in the well or vice versa, it should be noted whether the switches and cams are in proper alignment and are securely fastened. The slowing switches should operate sufficiently in advance of the stopping switches to enable the motor to reach its slow levelling speed before the application of the brake. The normal terminal stopping switches are frequently fitted on the car and are operated by cams in the well and these should receive careful attention. After inspection, all these switches should be tested by operating the car at normal speed between the extremes of travel.

**Upper Final Terminal Stopping Switch.** If this consists of a switch operated by a cam it may be inspected from the car top. Open the switch by hand and it should then be impossible to start the car. Check the cam and switch for rigidity and alignment. By measuring the distance between the two top terminal switches make sure that the final switch operates as soon as possible after the normal terminal stopping switch without interfering with the operation of the latter.

**Travelling Cable.** The fixing of this cable at the half-way box in the well may be examined whilst on the car top for any signs of looseness or breakage.

### (5) INSPECTIONS MADE FROM THE PIT

The pit will, of course, be entered from the bottom floor after the car has been raised from this floor about 4 feet by the winding handle and the gate lock opened with the emergency key. The car may then be lowered by hand sufficiently to permit the under-car equipment to be inspected.

**Bottom Final Terminal Stopping Switch.** This may be dealt with in a similar manner to that described for the top switch.

**Car Bottom Shoes.** Examine these as was done for the top pair.

**Car Sling.** Inspect the visible fastenings of the car frame and

if bolted note if the bolts are tight and also whether the platform is distorted.

**Travelling Cable.** The lower part of this cable and its fastening to the car should be inspected and the cable should not normally rest upon the pit floor.

**Car Safety Gear.** If instantaneous safeties are provided note whether the jaws and the safety block are clear of the guides during normal operation of the car. The governor should be tripped by hand and the empty car lowered by the winding handle until it rests on the safety jaws. Examine the jaws to see that they are engaged at both sides and note if the operating levers are free and adequately lubricated.

If of the wedge type, examine the jaws for freedom from contact with the guides and turn the drum by hand or pull the safety cable until the jaws touch the guides. Note that there is sufficient cable left on the drum so that it will not be pulled from the drum when the safety operates. See that the levers are adequately lubricated and that there is no excessive slack in the safety rope.

**Car and Counterweight Buffers.** If these are of the spiral or volute spring pattern examine to see that they fit vertically and securely in their bases and that the springs are not distorted.

With oil buffers ascertain that they have a sufficient supply of oil by inspecting the gauge provided on each and whether there is any sideplay in the pistons. If the counterweight buffers as well as the car buffers are mounted in the pit they will all be of the spring return type and may be partly depressed by standing on the top of the plunger. After release, the piston should return to its top position.

**Bottom Counterweight Guard.** See that this is in position and securely fixed.

**Governor Rope Pulley.** Inspect during operation to make sure that the pulley frame is free to slide in its guides and that the parts are adequately lubricated.

**Compensating Cable Pulley.** Examine as for governor rope pulley.

**Bottom Clearance.** The bottom counterweight clearance should be checked when the car is level with the top landing to ascertain if this has appreciably decreased due to rope

stretch. If it is necessary to shorten the ropes because of stretch, care must be taken to ensure afterwards that the bottom counterweight clearance is less than the top car clearance.

## ACCEPTANCE TESTS

Before a new lift is taken over from the manufacturers and put into commission, certain essential tests should be performed to ensure that the lift is satisfactory and conforms to the conditions laid down in the specification. The acceptance tests usually performed are detailed below.

It is desirable that the manufacturers supply and fix in the motor room a framed and glazed wiring diagram of the lift connexions for the use of the maintenance engineer, together with any maintenance recommendations which they wish to make. A plate should be fixed in the car showing the contract load, and in the case of passenger lifts, the maximum number of passengers to be carried, calculated at not less than 150 lb. per passenger. The actual requirements of different purchasers vary in detail, and if the lift has been manufactured and installed in accordance with a specification, it is necessary that those acceptance tests should be performed which will confirm whether the clauses of the specification have been fully met. In some instances the actual tests which will be applied are stated in the specification. Before carrying out any specified tests, the lift should be carefully examined and checked against the general requirements as regards type of equipment, construction of car and gates, type and fixings of guides and shoes, position of safety gear and buffers, methods of guarding, indicators, and other general items. After this has been done, the tests called for may be performed.

**Dead Load Test.** Frequently the equipment is required to sustain a load on the ropes equal to twice the maximum dead load borne in practice, for a period of about half an hour without showing signs of permanent distortion. It is desirable that this test be performed first so that any defect caused by weakness may possibly be revealed during subsequent tests. The car gate and landing gate leading pickets should be placed side by side and a horizontal line drawn on the leading edge of each picket, the car, during this operation, being stationed at the lowest floor. The car should be loaded with standard

weights of such value that the load in the car is equal to the weight of the car plus twice the contract load. On removing these weights, after the specified period, the amount of permanent set will be indicated by the vertical distance between the lines on the car and landing gate pickets. This set should not generally exceed $\frac{1}{8}$ in. to $\frac{1}{4}$ in. If the permanent set is abnormal, it may be traced to faulty rope fastenings or rope slip on a traction drive lift or to the brake drum slipping due to faulty brake adjustment. It is a good plan to mark the lifting ropes, the sheave and the brake drum before applying the weights, and thus any rope slip on the sheave or brake slip can readily be detected.

**Energy Consumption.** The contract load is required in the car for this test, and an energy meter connected in the supply to the lift, in such a manner that it indicates the sum of the motor and control consumptions. The consumption for a complete up and down journey is very small, and it will be necessary to take the average of, say, five complete journeys to obtain a reliable reading on the meter. When the marked rotating disc of the meter is visible, however, it is often possible to obtain the consumption for a complete journey by counting the number of revolutions made, and applying the ratio stamped on the meter. Excessive consumption may be accounted for by an inaccurate counterweight value.

**Full Load Levelling.** If the lift is equipped with automatic control, the accuracy of the floor setting gear may now be tested under full load conditions without altering the car loading from that used during the energy consumption test. The car should be called to each floor in turn when travelling in the up direction, and the actual distance that the car stops below each floor measured. Similarly, the stopping distances below each floor on the downward journey must be measured. These distances will be compared with the corresponding measurements taken later when the car is empty.

**Irreversibility.** Some authorities specify that their geared lifts must be self-sustaining and this may be checked by cutting off the control circuit and releasing the brake by hand, when the car, with full load, should remain stationary.

**Safety Gear Tests.** With the contract load still in the car, the safety gear may now be tested. If the lift operates from a

d.c. supply, the excess speed necessary to operate the gear may be obtained by field weakening, but if an a.c. motor is installed the gear may be set to operate at the contract speed or alternatively tripped by hand at the contract speed. Sometimes the governor sheave is provided with an extra groove of such a size that it will permit of the governor being driven at a speed corresponding to the safety gear tripping speed when the lift is travelling at its contract speed or special detachable extra governor test weights are supplied for the same purpose.

Instantaneous safety gear controlled by a governor should be tested with contract load and at contract speed, the governor being operated by hand. Two tests should be made, however, with wedge clamp or flexible clamp safeties, one with contract load in the car and the other with 150 lb. (equivalent to one person) in the car. The stopping distances obtained should be compared with the specified figures and the guides, car platform, and safety gear should be carefully examined afterwards for signs of permanent distortion. Note if there is sufficient cable left on the safety drum after the gear has operated.

Counterweight safety gear should be tripped by the counterweight governor and the stopping distances noted. In this case, however, the governor tripping speed should exceed that of the car safety governor, but by not more than 10 per cent.

**Governor Tripping Speed.** During the safety gear tests an inspector with a tachometer should determine the car speed (from the governor or the main sheave) at the instant of tripping. Check the tripping speed with that stated in Chapter XII. The governor jaws and rope should be examined for any undue wear.

**Contract Speed.** This should be measured with contract load in the car, the most convenient method being by counting the number of revolutions made by the sheave or drum in a known time. A chalk mark on the sheave or drum and a stop watch will facilitate counting and timing, but care must be exercised to ensure that no acceleration or retardation periods are included. If the roping is 2 to 1 the sheave speed is twice the car speed.

**Size of Car.** The floor area of the car should be measured in order to check that the passenger capacity plate is correctly engraved.

**Lift Balance.** Some of the weights should now be removed

until the remaining represent the balance figure specified, say, 50 per cent contract load. It should now be ascertained whether the counterweight is equal to the weight of the car plus 50 per cent contract load. This may be roughly checked by cutting off the supplies and rotating the winding handle in each direction in turn, and the effort required should be, as nearly as can be judged, the same. A more accurate test consists of wiring an ammeter in the motor supply and taking current readings during the upward and downward journeys. If the lift is properly balanced, these readings should be the same for each direction.

The remaining tests may be taken with no load in the car.

**Levelling Empty.** If the lift is automatically controlled, the car should be stopped during the upward journey at each floor in turn, and the stopping distances above each floor measured. The "up" levelling gear is correctly adjusted if these "high" distances are approximately equal to the "low" distances obtained during the up full load levelling test. Similar figures must be obtained during the down empty journey, and these distances above the floors should be equal to each other and the same as the "low" stopping figures taken during the down full load levelling test, if the down levelling gear is set correctly.

**Car and Counterweight Clearances.** The bottom car clearance and the top counterweight clearance may be measured with the car level with the bottom landing. In taking these measurements it may be more convenient to station the car a couple of feet above the bottom landing so that entrance to the pit is made easier. Due allowance must, of course, be made for the distance the car rests above the landing. The top car and bottom counterweight clearances must be obtained from the top of the car and the pit respectively with the car at the top landing. Particular care should be taken to note that the latter clearance is the smaller.

The clearance between the car and the landing sill should be between $\frac{1}{2}$ in. and $1\frac{1}{2}$ in. and between the car and the well enclosure opposite the car entrance not more than 5 in. The maximum clearance between the landing door and the edge of the landing threshold should be 4 in.

**Car and Landing Gates.** The lift should not operate with any gate open. The car gate delay contact and the retiring lock release cam must be tested.

**Controller.** The operation of the contactors and interlocks should be examined, also any time lag contacts, and it should be ascertained whether all the requirements laid down in the specification have been met. Insulation tests must be taken on both motor and control circuits at 500 volts d.c. with all wiring in circuit in each case.

The method of earthing the controller and all other electrical equipment should be inspected and tested. An earthing point should be available in the machine room and this will usually be the sheathing or conduit of the incoming supply cable. This earth should be extended to the metal parts of all the lift electrical equipment except, of course, the current-carrying parts and this is usually done either by continuous screwed conduit or separate earth conductors. These latter should be not smaller than 7/0·029 conductors. The frames of the motors, generators and rectifiers if not earthed by conduits, should be earthed by 7/0·029 or 7/0·064 conductors if the name plate ratings do not exceed 50 and 100 amps. respectively and by 19/0·064 conductors if the rating exceeds 100 amps. The controller frame should be earthed similarly and a separate earthing lead should be provided in the trailing cable for earthing the electrical equipment in the car. The resistance to earth at any point in the earthing system must not exceed 1 ohm.

**Acceleration and Retardation.** It can be judged whether these are sufficiently smooth by riding in the car.

**Normal Terminal Stopping Switches.** Test by letting the car run to each terminal landing in turn, first with no load, and then with contract load in the car. By taking measurements the top and bottom over-travels can be ascertained.

**Final Terminal Stopping Switches.** The normal slowing switches must be disconnected for this test either by removing the roller from the switch arm or short-circuiting the slowing switches. It is necessary to ensure that these final switches open as close to the normal switches as possible (by measurements) without interfering with the normal stops. If spring buffers are fitted, the final switches must open before the buffers are engaged. With oil buffers the top final terminal switch is tested by arranging for the empty car to strike the switch at half contract speed. The bottom final terminal switch is

tested by running the loaded car down so that it strikes the switch at half contract speed. In each case the buffers must be operative.

**Oil Buffers.** The oil buffers are examined after the above tests have been made to determine if there has been any oil leakage or distortion and to ensure that the buffers return to their normal positions.

**Ropes.** The size, number, construction and fastenings of the ropes should be carefully checked and recorded.

# CHAPTER XVII

## LIFT ACCIDENTS

COMPLETE information relating to accidents which have occurred on lifts in this country is not available in any publication and it is doubtful whether such records, useful as they would undoubtedly be, have ever been compiled and preserved. In addition to details of accidents which appear from time to time in the Press, there is the large number, usually less serious, which have occurred and are known only to those closely connected with the persons or lifts concerned. Probably the most comprehensive records of lift accidents are those kept by the Chief Inspector of Factories but even these relate only to accidents that have occurred in factories, and furthermore, which have been reported to his Department. Nevertheless, the information which has been published regarding these is valuable and gives much food for thought.

Lift accidents may be divided broadly into two classes: those due to faulty design or maintenance and those caused by foolishness on the part of users, such as tampering with safety devices. It seems clear that by far the larger number can be attributed to the first cause, and accidents, particularly fatal ones, are now very rare indeed on well designed and adequately maintained lifts. The Code of Practice for the Installation of Lifts and the Factories Act now prescribe definite standards to be observed in safeguarding lifts, these standards being in accordance with the modern practices of the best lift makers. Although in many cases heavy expenditure has been necessary to alter old type lifts so that they conform to these modern requirements, it is clear, certainly as regards factory lifts, that definite and considerable progress has been made since 1937. The gradual decrease in accidents since this year, as shown by the Chief Inspector of Factories reports, has been due to the observance of the safety requirements of the Act, and in particular the periodical inspections required.

The table* on p. 364 shows the number of accidents that have

* Annual Report of the Chief Inspector of Factories 1949—H.M. Stationery Office (*reproduced by permission of the Controller, H.M. Stationery Office*).

occurred in the fourteen years 1936–1949, but it must be stressed that these figures refer to all types of hoists and lifts installed in factory premises only. The striking effect of the improvements in design and maintenance of these hoists and lifts due to the Factories Act is clearly shown and would undoubtedly have been still more marked but for the intervention of the war years. During this period the shortage of labour and materials prevented the completion of all the work necessary to bring hoists and lifts up to the full requirements of the Act.

ACCIDENTS ON HOISTS AND LIFTS

| *Year* | *Total Accidents* | *Fatal Accidents* |
|---|---|---|
| 1936 | 490 | 20 |
| 1937 | 432 | 29 |
| 1938 | 304 | 13 |
| 1939 | 285 | 15 |
| 1940 | 355 | 20 |
| 1941 | 292 | 10 |
| 1942 | 246 | 12 |
| 1943 | 193 | 13 |
| 1944 | 158 | 2 |
| 1945 | 155 | 7 |
| 1946 | 176 | 12 |
| 1947 | 146 | 5 |
| 1948 | 115 | 6 |
| 1949 | 102 | 5 |

It is still more interesting and instructive to analyse the precise causes of these accidents as has been done in the table* on page 365 for the years 1937, 1938, and 1947.

By far the largest number of accidents was caused by crushes between the car and the landing, and this emphasizes the importance of satisfactory protection for the car and landing openings. It is quite likely that many of these accidents occurred on old lifts which had totally inadequate protection for the car or landing openings and it is probable that most of these accidents and many of the crushes between the car and well projections would have been avoided if doors or mid-bar gates had been fitted. Inadequate or unsuitable well enclosures were responsible for another big number of accidents.

Proceeding a stage further in the analysis of these accidents, the following are brief descriptions of actual typical accidents

* Annual Reports of the Chief Inspector of Factories 1938 and 1949—H.M. Stationery Office (*reproduced by permission of the Controller, H.M. Stationery Office*).

HOIST AND LIFT ACCIDENTS 1937, 1938, AND 1947*
(On premises under the Factories Act)

| Causation | Total 1938 | | Total 1937 | | Total 1947 | |
|---|---|---|---|---|---|---|
| | Fatal | All | Fatal | All | Fatal | All |
| A. *Falls.* | | | | | | |
| 1. Falls down hoist well when— | | | | | | |
| (*a*) Entirely unfenced | 1 | 3 | 2 | 7 | — | 1 |
| (*b*) Fenced—single bar | 1 | 3 | — | 1 | 1 | 1 |
| Doors left open— | | | | | | |
| (*c*) Creeping cage | 2 | 7 | — | 2 | — | 1 |
| (*d*) Cage moved by someone else | — | 9 | 1 | 6 | — | — |
| (*e*) Other than (*c*) or (*d*) | — | 3 | — | 3 | — | 1 |
| (*f*) Injured person opened doors | 2 | 10 | 1 | 12 | — | 7 |
| (*g*) Auto. gates propped open or out of order | — | 1 | 2 | 9 | — | 5 |
| (*h*) Hoist creeping upset load when unloading | — | 1 | — | — | — | — |
| 2. Fall of cage through— | | | | | | |
| (*a*) Breaking of suspension rope | — | 7 | — | 14 | — | 7 |
| (*b*) Leakage or failure of hydraulic valve | — | 1 | — | — | — | — |
| (*c*) Other causes | — | 9 | 2 | 18 | — | 9 |
| 3. Falls of persons or articles— | | | | | | |
| (*a*) Getting in or out of cage in motion | — | — | — | 4 | — | 1 |
| (*b*) Other falls of persons out of cage | — | 2 | — | 4 | — | — |
| (*c*) Bodies falling out of cage | — | 6 | 1 | 8 | — | 1 |
| (*d*) Articles falling on persons in cage through open top | — | 2 | — | 3 | — | 1 |
| (*e*) Article in cage, falling on person in it | — | 5 | — | 2 | — | 2 |
| B. *Crushes.* | | | | | | |
| 1. Between cage and fencing of well | 1 | 13 | 4 | 30 | — | 3 |
| 2. Between cage and structure of well— | | | | | | |
| (*a*) Cage ascending—top of doorways or floors of room | 2 | 64 | 8 | 97 | — | 28 |
| (*b*) Cage descending—between cage and floor of room | 1 | 48 | 2 | 50 | 1 | 9 |
| (*c*) Projections in well | 1 | 30 | 2 | 36 | — | 10 |
| (*d*) No projections in well | — | 8 | 1 | 24 | — | 4 |
| (*e*) Cage and top of well | 1 | 3 | — | 7 | — | 1 |
| (*f*) Cage and bottom of well | — | 3 | — | 7 | 1 | 4 |
| 3. Between truck and inside of cage | — | 8 | — | 12 | — | 3 |
| C. *Miscellaneous.* | | | | | | |
| 1. Injured by— | | | | | | |
| (*a*) Automatic gates | — | 8 | 1 | 27 | 1 | 17 |
| (*b*) Counterbalance weights | 1 | 8 | 1 | 9 | — | 2 |
| (*c*) Gear of hoist, starting or suspension ropes, etc. | — | 12 | — | 10 | — | 5 |
| 2. Continuous hoists | — | 5 | — | 3 | — | — |
| 3. Unclassified causes | — | 25 | 1 | 27 | — | 2 |
| D. *Repairing, Cleaning or Oiling (included in above)* | (3) | (15) | (2) | (17) | — | 11 |
| Total | 13 | 304 | 29 | 432 | 4 | 136 |

The figures for 1947 are for *power* operated lifts and hoists.

which have occurred in factories and which have been notified to H.M. Chief Inspector of Factories.* The references relate to the volume number and accident number in the publication, "How Factory Accidents Happen."

(1) *Vol. I, No.* 2. An electric lift was fitted with interlocked collapsible gates on the landings and on both the front and back entrances to the car. A boy riding up in the car leaned against the back gate and thoughtlessly put his foot between the gate pickets. His heel was trapped between the floor of the car and a door lintel four inches from the edge of the car floor. The jamming of the car brought the safety gear into action, but the boy's foot had to be amputated before he could be released.

This accident could have been prevented by the use of mid-bar gates.

(2) *Vol. II, No.* 12. An electric lift with automatic control was fitted with interlocked collapsible gates on the car and at each landing. A man had just left the car and had closed both gates when he noticed that he had forgotten to switch off the car light. He attempted to reach the switch by reaching into the car between the pickets of both gates. At that moment the car was called to another landing by a person at that landing. The man's arm was consequently very seriously injured.

If the gates had been of the mid-bar pattern, or the car buttons and switches placed so as to be inaccessible from the landing, this could not have happened.

(3) *Vol. II, No.* 13. A painter was killed when engaged in painting the trellis work fence of a lift well in a new building which was let out to tenants for office purposes. The lift was electrically driven, with automatic control, and at the time of the accident the man was on top of the car. A tenant pressed one of the landing buttons, the lift ascended to the top of the well, and the painter was crushed under one of the girders of the well structure.

The circumstances showed that no real attempt had been made to protect this worker against such risk apart from his being advised to leave one of the gates open. Such work should only have been carried out after opening the main switch.

* "How Factory Accidents Happen," H.M. Stationery Office (*reproduced by permission of the Controller, H.M. Stationery Office*).

(4) *Vol. IV, No.* 4. The lift in question had collapsible gates on each landing and on the car, automatic control and a car floor switch. An office cleaner in the car, with the landing gate shut and the car gate open, was standing close up to the landing gate (and so not depressing the hinged spring floor and thus keeping the car gate contacts short-circuited) for the purpose of cleaning a window-ledge on the far side of the stairway which surrounded the lift. A person at another floor then called the lift and the woman was fatally crushed between the car and the side of the well.

Following the accident, the gaps in the well, which invited cleaning to be done from the car, were filled in. Car floor switches, however, are dangerous and should be put out of action if already provided in existing lifts. Most authorities now prohibit their use on new lifts.

(5) *Vol. IV, No.* 5. The sides of the well of a warehouse lift were fenced by wire mesh panels to a height of 6 ft. 6 in. at each floor. The clearance between the counterweight and the fencing was 3½ in. A man wishing to ascertain the position of the car stood on an iron drum and looked over the top of the fencing. At that moment the car was ascending and the man's head was squeezed between the counterweight and the fencing. Fortunately the wire mesh gave way sufficiently to prevent the man from being killed, but he was severely injured.

If the well had been guarded from floor to ceiling this accident could not have happened.

(6) *Vol. IV, No.* 7. A boy was killed by having his head crushed between a shelf in the car of a small service lift and the top of the doorway. The well was enclosed but no protection was provided at the lower doorway, although at the upper level a fire-proof door was fitted. The lift was electrically driven and was controlled by push buttons near each doorway. The boy put his head inside the car whilst it was at the lower level and shouted up the well; at the same time he inadvertently set the car in motion by pressing one of the push buttons. As a result his head was trapped between the shelf and the top of the doorway.

This illustrates the need for fencing, even on small lifts. Doors or gates should have been provided with full interlocks.

(7) *Vol. VII, No.* 2. An employee of a firm of lift engineers was killed and another man injured while engaged on re-roping a 10 cwt. electric goods lift. The car was fitted with serrated steel cam safety gear and this was engaged with the wooden guides in order to support the car. One of the men stood on a step ladder inside the car, with the upper part of his body through the emergency exit. The second man entered the car to give assistance and at that moment the car fell to the bottom of the well. It was found that the safety gear had torn the timber guides and one of the cams had turned over on its shaft.

This illustrates the need for careful design and maintenance of the safety gear and the advisability of using lifting tackle to support the car when re-roping.

(8) *Vol. VII, No.* 3. Two workmen were greasing and oiling a modern passenger lift, but before the work began the man in charge went away to attend to another matter, leaving his mate in the bottom of the 7 feet deep pit. When the charge-hand returned, he signalled to the car attendant for the car to descend to the basement level. At that moment the man in the pit tried to scramble out by climbing up to the landing doors but was struck by the car and received fatal unjuries. He would have been perfectly safe if he had remained in the pit.

This shows the care that must be taken by maintenance men for their own safety and the need to understand thoroughly the principles of their job.

(9) *Vol. VIII, No.* 9. The lift had automatic control and fully interlocked collapsible gates on the landings and car. A man was asked to take the lift down to another floor, but instead of accompanying it he closed the gates, put his arm between the pickets, and operated the car push button. Fortunately he was able to stop the lift before serious injury was done to his arm.

Such accidents are prevented by the use of mid-bar gates and it is also an advantage to place the car buttons out of reach of a person on a landing.

(10) *Vol. IX, No.* 10. A liftman was injured when his car fell from the ground to the basement of a factory. The lift was electrically driven, had worm gear, a *V* sheave, two suspension ropes, and a diverting pulley. The examination after the collapse showed that over a considerable length, the rope wear

was serious, and it was also found that the diverting pulley could not revolve freely on its shaft. The excessive wear was obviously due to the friction of the ropes in the pulley grooves.

This accident would have been prevented if there had been regular and thorough maintenance, which would have revealed the seized pulley and stopped the ropes wearing. The fitting of car safety gear operated on the broken rope principle would have prevented the car from falling.

(11) *Vol. X*, *No.* 3. The electric lift concerned was of the fully automatic type, with interlocked car and landing gates, a car floor switch, and arranged so that the empty car returned automatically after a brief interval to the ground floor. A workman, whilst painting the inside of the car, was requested by his mate, who was painting the outside of the car from a position on the fifth floor, to move the car a few feet downwards. Having done so, he then opened the car gate and stood on the narrow landing edge sufficiently long for the timing device to bring about the automatic descent of the car. He was trapped and killed.

This reveals the danger attending the use of car floor switches, but the accident would not have occurred if the floor of the car had been temporarily weighted down. The landing gates should be as close as possible to the edge of the landing floor, which would also minimize the risk.

(12) *Vol. X*, *No.* 4. A workman had crawled into the lift pit to limewash the lower part of the lift well. The understanding between this man and the lift attendant was that the car should be taken to the top landing and left there until all the limewashing within reach was finished. The workman overlooked the fact that as the car moved up the counterweight moved down. He failed to keep clear of the weight, was struck by it and fatally injured.

If a pit counterweight guard had been fitted this accident would not have happened.

(13) *Vol. XII*, *No.* 1. A maintenance man obtained access to the top of the lift car by removing the emergency exit panel in the roof. After completing the work he left the car, but remembering that he had inadvertently refixed the panel upside down, returned later in the day to turn it over. He got on top of the car through one of the landing gates, but owing to

some misunderstanding with the lift attendant the car was taken up when the maintenance man was in an unsafe position. His back came in contact with one of the guide brackets and he subsequently died from his injuries.

The attendant should have acted entirely under the orders of the man on top of the car. If the exit had been fitted with an interlock switch, however, the accident could not have occurred.

(14) *Vol. XIII, No.* 9. An electric lift was fitted with automatic control, interlocked gates, and a car floor switch. There was, however, a landing space of 10 in. between the car and the landing gates, and a girl leaving the lift stood in this space prior to opening the landing gate. At that moment the lift was called to another landing. The girl was severely injured and fell to the bottom of the well, her injuries proving fatal.

Floor switches should not be used, and the landing gates should be fitted as close as possible to the edge of the well opening.

(15) *Vol. XV, No.* 8. A lightly loaded truck had been taken from the first floor to the basement of a building in the car of a lift serving six floors. A man in the car had pushed the truck half-way out when the car began to ascend. The truck fell out and the car crashed into the top of the well; the man was bruised and his head cut. The cause of the accident was the detachment of the bronze rim of the worm wheel from its centre; one of the bolts had fallen out and the others had sheared. The brake was therefore ineffective and the heavier counterweight took control.

If there had been regular inspections—this worm had not been examined during its ten years life—the defective fastening of the rim would almost certainly have been discovered. It appears also that, for the car to crash at the top of the well, the top car clearance must have been inadequate—a badly designed lift.

(16) *Vol. XVI, No.* 20. The lift was a modern electric one with "self-levelling" gear in which the doors commenced to open when the car reached the levelling zone, which was a few inches from the landing. A man standing on a landing had his foot trapped under the car whilst it was descending slowly

to the landing. On investigation it was found that the apron plate fitted to the front edge of the car was of insufficient depth to fill the maximum possible gap.

It is necessary to ensure that the depth of the apron board is greater than the distance from the landing to the edge of the landing zone.

(17) *Vol. XVI, No.* 21. A boy entered a lift car and while both the car and landing gates were open the car began to descend. The boy was alarmed and tried to scramble out, but he was trapped between the top of the car and the landing. He instantly screamed and the car came to rest. It appears that the lift would not respond to the operation of the car switch and the attendant went to the motor room with another man to find the cause of the trouble. When there he operated one of the contactors by hand, thus setting the car in motion. The probable cause of the original failure to operate was a door not properly closed, as no defect was found in any part of the mechanism.

It is important that only a skilled maintenance engineer should have access to a lift motor room.

(18) *Vol. XVII, No.* 10. The car of a fully automatic lift had been called to the third floor but came to rest below the landing and the gate could not be opened. A girl on the landing, in an endeavour to level the car, reached through the two gates and pressed one of the car buttons. The car began to descend and her arm was sheared between the two gates and badly injured. The car gate was of the mid-bar type but the landing gate of the open picket pattern.

If the landing gate had been of the mid-bar type, or a solid door had been fitted, it would have been impossible to reach the car buttons. Suitably placed car buttons or a safety plate fitted to the gate would have prevented this accident.

(19) *Vol. XVII, No.* 11. A large stand had been placed in the car of a goods lift for conveyance to an upper floor and one of the men found that he could get out of the car only by climbing over the top of the stand. While he was doing so the stand rocked and pressed one of the car buttons. In spite of the fact that the gate was open and was fitted with an interlock, the car began to ascend and the man's leg was caught between the stand and the lintel of the doorway. It was found

afterwards that a spring in the interlock was broken and the contacts thus remained closed when the gate was open.

This illustrates the importance of a thorough examination of the interlocks during the periodical inspections.

(20) *Vol. XVII, No.* 12. A painter's labourer went into a lift motor room and his trousers were caught by the square end of the motor shaft which projected 2 in. beyond the motor casing. Both his legs were cut and bruised.

The square end is necessary to permit winding of the car by hand, but it should be covered by a cap or an open ended shield.

(21) *Vol. XVIII, No.* 10. A man took a drum-driven goods lift up to the upper level and as he was stepping out the car fell and trapped him against the platform, causing fatal injuries. The spur wheel was found to be broken and the motor burnt out. It appears that in the absence of a lower landing limit switch the drum had on some previous occasion continued to revolve after the car had come to rest and the suspension ropes had been taken round the drum in the wrong direction. The men had been in the habit of throwing the car switch to the "down" position when they wanted to go up. When the car was at the upper level, the ropes were consequently at an acute angle to the horizontal instead of being vertical and the rope tension and the torque on the drum and gear shaft were excessive. It was this abnormal pull on the ropes which caused the fracture of the gear wheel.

Limit switches and a slack rope switch are necessary on drum-driven lifts.

(22) *Vol. XX, No.* 14. Two men were taking ironmongery from the ground floor to the basement in an electric lift driven through worm gear and a "V" sheave. They loaded the car without making any estimate of the weight put in, then one man walked down the stairs, leaving his mate to travel down with the goods. When the first man arrived at the basement he looked up and saw his mate trapped between the top of the car and the ground floor. The gate interlocks were subsequently found to be out of order. The accident was undoubtedly due to gross overloading and it was not probable that the gearing was driven "backwards" by the overload. It was not possible to establish the real cause, but the ropes may have pulled through

the sheave grooves and the unexpected movement caused the man to fall over.

A lift car should never be loaded beyond the loading specified in the car. Automatic safe-load indicators which give a visible or an audible warning of overloading may be fitted on lifts.

(23) *Vol. XXI, No.* 7. A man in an automatic lift was taking a load of tea chests from the top floor to the bottom. One of the chests was trapped between the edge of the landing (where there was a space 2 in. wide inside the landing gate) and the top of the car, the car jammed and was brought to rest. At that moment another person pressed the bottom floor button and as it was a drum drive, several feet of the suspension ropes were wound off the drum and hung loose above the car. The projecting chest was knocked back into the car, which immediately fell the few feet of the slack rope. The overhead timber beams, carrying the pulleys, broke and the car fell to the bottom of the well.

The accident would have been prevented if the car gate had been fitted with an electric interlock.

(24) *Vol. XXV, No.* 10. An electrician was on a ladder, wiring conduit near an electric goods lift. The space between the top of the gate and the floor above was not fenced and the man's elbow, projecting into the well, was trapped between the top of the car and an angle iron bracing fitted across the well opening. The man's arm was badly cut.

Well fencing should extend from floor to ceiling on all sides.

(25) *Vol. XXV, No.* 11. After a concert in a large factory, thirty-one people crammed themselves into the car of a lift. The load then was about twice the contract load and the car began to slide down, the ropes slipping through the "V" sheave grooves. When the car struck the bottom several people were injured.

A conspicuous notice showing the maximum number of people to be carried should be placed in every lift, as well as the maximum working load, and the attendant should be given sufficient authority to prevent this from being exceeded.

(26) *Vol. XIII (New Series) No.* 5. Two men had just entered a lift car after having loaded it when, without the controls being actuated, the car moved downwards. One of the men tried to get out of the car and fell awkwardly, breaking

his leg. The lift was not overloaded, but investigation showed that the four suspension ropes which were in good condition were coated with thick oil. This oil caused the ropes to slip on the sheave. The tendency to slip was increased by the presence of a diverting pulley which reduced the angle of contact between the rope and the sheave by 26 per cent. With a traction sheave the drive depends on the grip of the ropes in the sheave grooves, and rope lubrication should be kept to a minimum.

Other factors which affect slipping, e.g. angle and condition of the sheave grooves, did not apply in this case.

(27) *Vol. XIII (New Series) No.* 6. An engineer was examining the suspension rope of a lift in the machine room by allowing it to pass through his gloved hands as the lift was moved slowly. The needled ends of some broken wires caught his gloves and carried his hands into the "nip" between the rope and the groove sheave, where they were trapped and severely injured. Had the man not been wearing gloves it is likely that the accident would not have occurred. The proximity of the sheave increased its severity, but in any case the method of examining a wire rope by allowing it to be moved through the hands is a dangerous one.

(28) *Vol. XV (New Series) No.* 20. A painter, wishing to get a 12-ft. ladder up to the fifth floor of a factory, decided to put it in the lift rather than carry it up the stairway. The trap door in the roof of the car was opened and the ladder was placed in the car with about 5 ft. of it projecting above the roof. As the car ascended, the projecting end of the ladder was caught by the descending counterweight in the well. The end of the ladder in the car struck one of the two men travelling with it, breaking his leg in two places.

The accident illustrates the danger of carrying anything in a lift car which projects through the roof. In this case the ladder struck the counterweight, but it might also have caught on projections in the well, or, if the car had gone to the top floor, it might have struck the top of the lift well. If the trap door had been fitted with an electric interlock, this accident could not have happened.

(29) *Vol. XVII (New Series) No.* 7. A workman entered the ground floor of a warehouse and opened the landing gate of an

electric lift, expecting the car to be at that landing. The car was not there, however, and he fell 15 ft. into the basement, receiving severe injuries. Examination of the gate lock showed that it was in a bad state of repair, which accounted for the injured person being able to open the gate when the car was not at that landing. The locking plate was badly bent, and the internal fittings were loose, so that although the electric part of the lock was in order, the mechanical locking mechanism was ineffective. A lift landing gate lock should not only prevent the car being moved unless the landing gate is closed, but should also prevent the opening of the gate unless the car is at the landing.

The examination of the landing gate locks is a very important part of the statutory six monthly examination of a lift.

(30) *Vol. XVII (New Series) No.* 8. A workman loaded some barrels into an electric lift and then travelled in the car with them to a lower floor. On the way down he moved the car switch to the OFF position and began to tie up his shoelace. He noticed, however, that the car was continuing to descend, and before he could do anything it struck the buffers at the bottom of the well. The impact displaced the barrels and the man received leg injuries.

The safe working load of the lift was 30 cwt., and the weight of the barrels and the man amounted to 31½ cwt. Examination of the brake showed that it was in a bad state of repair. The brake linings were badly worn and cracked, and the brake was obviously in no condition to sustain the car even when carrying its proper load.

Regular and careful maintenance would have prevented this accident.

The above cases are typical examples of lift accidents, from which the usual causes of such accidents will be evident. The conclusions to be drawn from the information provided in this chapter are that if lifts are constructed and maintained in such a manner that the requirements of the Factories Act are fulfilled and the safety recommendations made in this book are adopted, the possibility of an accident occurring will be very remote.

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# APPENDIX I

## FACTORIES ACT, 1937: REGULATIONS RELATING TO LIFTS

### Section 22. Hoists and Lifts.

(1) Every hoist or lift shall be of good mechanical construction, sound material and adequate strength, and be properly maintained.

(2) Every hoist or lift shall be thoroughly examined by a competent person at least once in every period of six months, and a report of the result of every such examination in the prescribed form and containing the prescribed particulars shall be signed by the person making the examination and shall within fourteen days be entered in or attached to the general register.

(3) Every hoistway or liftway shall be efficiently protected by a substantial enclosure fitted with gates, being such an enclosure as to prevent, when the gates are shut, any person falling down the way or coming into contact with any moving part of the hoist or lift.

(4) Any such gate as aforesaid shall be fitted with efficient interlocking or other devices to secure that the gate cannot be opened except when the cage or platform is at the landing and that the cage or platform cannot be moved away from the landing until the gate is closed.

Provided that, in the case of a hoist or lift constructed or reconstructed before the passing of this Act which it is not reasonably practicable to fit with such devices as aforesaid, it shall be sufficient if the gate is provided with such arrangements as will secure the aforesaid objects so far as is reasonably practicable, and in any event is kept closed and fastened except when the cage or platform is at rest at the landing.

(5) Every hoist or lift and every such enclosure as aforesaid shall be so constructed as to prevent any part of any person or any goods carried in the hoist or lift being trapped between any part of the hoist or lift and any fixed structure or between the counterbalance weight and any other moving part of the hoist or lift.

(6) There shall be marked conspicuously on every hoist or lift the maximum working load which it can safely carry and no load greater than that load shall be carried on any hoist or lift.

(7) The following additional requirements shall apply to hoists and lifts used for carrying persons, whether together with goods or otherwise—

(*a*) efficient automatic devices shall be provided and maintained to prevent the cage or platform overrunning;

(*b*) every cage shall on each side from which access is afforded to a landing, be fitted with a gate, and in connexion with every such gate efficient devices shall be provided to secure that, when persons or goods are in the cage, the cage cannot be raised or lowered unless the gate is closed, and will come to rest when the gate is opened: Provided that, in the case of a hoist or lift constructed or reconstructed before the passing of this Act in connexion with which it is not reasonably practicable to provide such devices as aforesaid, it shall be sufficient if such arrangements are provided as will secure the aforesaid objects so far as is reasonably practicable, and in any event the gate is kept closed and fastened except when the cage is at rest or empty; and

(*c*) in the case of a hoist or lift constructed or reconstructed after the passing of this Act, where the platform or cage is suspended by rope or chain, there shall be at least two ropes or chains separately connected with the platform or cage, each rope or chain and its attachments being capable of carrying the whole weight of the platform or cage and its maximum working load, and efficient devices shall be provided and maintained which will support the platform or cage with its maximum working load in the event of a breakage of the ropes or chains or any of their attachments.

(8) In the case of a continuous hoist or lift, subsections (3) to (7) inclusive of this section shall not apply and in the case of a hoist or lift not connected with mechanical power subsections (4) and (7) shall not apply, and, in both the aforesaid cases, in subsection (2) for the reference to six months there shall be substituted a reference to twelve months.

(9) For the purposes of this section, no lifting machine or

appliance shall be deemed to be a hoist or lift unless it has a platform or cage the direction of movement of which is restricted by a guide or guides.

(10) Every teagle opening or similar doorway used for hoisting or lowering goods or materials, whether by mechanical power or otherwise, shall be securely fenced, and shall be provided with a secure handhold on each side of the opening or doorway. The fencing shall be properly maintained and shall, except when the hoisting or lowering of goods or materials is being carried on at the opening or doorway, be kept in position.

(11) If it is shown to the satisfaction of the Secretary of State that it would be unreasonable in the special circumstances of the case to enforce any requirement of this section in respect of any class or description of hoist, lift, hoistway, liftway, or teagle opening or similar doorway, he may by order direct that such requirement shall not apply as respects that class or description.

## Section 23. Chains, Ropes and Lifting Tackle.

(1) The following provisions shall be complied with as respects every chain, rope, or lifting tackle used for the purpose of raising or lowering persons, goods, or materials—

(*a*) no chain, rope, or lifting tackle shall be used unless it is of good construction, sound material, adequate strength, and free from patent defect;

(*b*) a table showing the safe working loads of every kind and size of chain, rope, or lifting tackle in use, and, in the case of a multiple sling, the safe working load at different angles of the legs, shall be posted in the store in which the chains, ropes, or lifting tackle are kept, and in prominent positions on the premises, and no chain, rope, or lifting tackle not shown in the table shall be used, so, however, that the foregoing provisions of this paragraph shall not apply in relation to any lifting tackle if the safe working load thereof or, in the case of a multiple sling, the safe working load at different angles of the legs, is plainly marked upon it;

(*c*) no chain, rope, or lifting tackle shall be used for any load exceeding the safe working load thereof as shown by the table aforesaid or marked upon it as aforesaid;

(*d*) all chains, ropes, and lifting tackle in use shall be thoroughly examined by a competent person at least once in every period of six months or at such greater intervals as the Secretary of State may prescribe;

(*e*) no chain, rope, or lifting tackle except a fibre rope or fibre rope sling, shall be taken into use in any factory for the first time in that factory unless it has been tested and thoroughly examined by a competent person and a certificate of such a test and examination specifying the safe working load and signed by the person making the test and examination has been obtained and is kept available for inspection;

(*f*) every chain and lifting tackle except a rope sling shall, unless of a class or description exempted by certificate of the chief inspector upon the ground that it is made of such material or so constructed that it cannot be subjected to heat treatment without risk of damage or that it has been subjected to some form of heat treatment (other than annealing) approved by him, be annealed at least once in every fourteen months, or, in the case of chains or slings of half-inch bar or smaller, or chains used in connexion with molten metal or molten slag, in every six months, so, however, that chains and lifting tackle not in regular use need be annealed only when necessary;

(*g*) a register containing the prescribed particulars shall be kept with respect to all such chains, ropes, or lifting tackle, except fibre rope slings.

(2) In this section the expression "lifting tackle" means chain slings, rope slings, rings, hooks, shackles, and swivels.

The following sections, although not specifically referring to lifts, must receive consideration during the design and installation of lifts, and in cases of doubt it is advisable to consult the District Inspector of Factories.

### Section 12, Para. (3).

Every part of electric generators, motors, and rotary converters, and every flywheel directly connected thereto, shall be securely fenced unless it is in such a position or of such construction as to be as safe to every person employed or working on the premises as it would be if securely fenced.

**Section 13.**

(1) Every part of the transmission machinery shall be securely fenced unless it is in such a position or of such construction as to be as safe to every person employed or working on the premises as it would be if securely fenced.

(2) Efficient devices or appliances shall be provided and maintained in every room or place where work is carried on by which the power can promptly be cut off from the transmission machinery in that room or place.

(3) No driving-belt when not in use shall be allowed to rest or ride upon a revolving shaft which forms part of the transmission machinery.

**Section 14, Para. (1).**

Every dangerous part of any machinery, other than prime movers and transmission machinery, shall be securely fenced unless it is in such a position or of such construction as to be as safe to every person employed or working on the premises as it would be if securely fenced:

Provided that, in so far as the safety of a dangerous part of any machinery cannot by reason of the nature of the operation be secured by means of a fixed guard, the requirements of this subsection shall be deemed to have been complied with if a device is provided which automatically prevents the operator from coming into contact with that part.

**Section 17.**

(1) In the case of any machine in a factory being a machine intended to be driven by mechanical power—

(*a*) every set-screw, bolt or key on any revolving shaft, spindle, wheel or pinion shall be so sunk, encased or otherwise effectively guarded as to prevent danger; and

(*b*) all spur and other toothed or friction gearing, which does not require frequent adjustment while in motion shall be completely encased unless it is so situated as to be as safe as it would be if completely encased.

(2) Any person who sells or lets on hire or, as agent of the seller or hirer, causes or procures to be sold or let on hire for use in a factory in the United Kingdom any machine intended

to be driven by mechanical power which does not comply with the requirements of this section shall be guilty of an offence and liable to a fine not exceeding £100.

**Section 36, Para. (4).**

Every hoistway or liftway inside a building constructed after the coming into operation of this section shall, subject as hereinafter provided, be completely enclosed with fire-resisting materials, and all means of access to the hoist or lift shall be fitted with doors of fire-resisting materials:

Provided that any such hoistway or liftway shall be enclosed at the top only by some material easily broken by fire or be provided with a vent on the top.

**Statutory Rules and Orders 1938, No. 489—The Hoists Exemption Order, 1938.**

In accordance with the provisions of subsection (11) of section 22 of the Factories Act 1937 (as detailed earlier in this Appendix) this Exemption Order states that the requirements of some subsections of Section 22 shall not apply to certain types of hoists subject to conditions which are specified in the Order. In this Order the expressions "hoist" and "hoistway" include "lift" and "liftway" respectively. Details of the exemptions are as follows—

(1) Hoistways of pavement hoists, that is to say hoists in the case of which the top landing is the surface of a street or public place, or of a yard or other open space within a factory where persons are required to pass. In these hoistways subsection (3) shall not apply in so far as it requires the hoistway to be protected by an enclosure and gate at or above the top landing, but the hoistway shall be securely covered or securely fenced at the top landing except when and where access is required for persons, goods or materials. In addition, subsection (4) shall also not apply except in the case of a hoist with more than one landing other than the top landing, but every gate shall be kept closed and fastened except when the cage or platform is at the landing.

(2) Hoistways of hoists of movable type which are used for the stacking, loading, or unloading of goods or materials but not for carrying persons and which do not pass through

any floor. In these hoistways subsection (3) and (4) shall not apply.

(3) Hoistways of hoists not of movable type which are used for the stacking, loading or unloading of goods or materials, and which do not pass through any floor, and in the case of which the height of travel of the cage or platform exceeds five feet. In these hoistways subsections (3) and (4) shall not apply but the hoistway shall, so far as is reasonably practicable, be protected at ground or floor level by an enclosure not less than 7 ft. in height and fitted with a gate or gates in connexion with which subsection (4) shall apply; and if the hoist is used for carrying persons it shall be provided with a cage.

(4) Hoistways of hoists not of movable type which do not pass through any floor, and in the case of which the height of travel of the platform does not exceed 5 ft. In these hoistways subsections (3) and (4) shall not apply but a gate or gates or other fittings shall be provided to prevent any person being endangered by the underside of the platform.

(5) Hoistways of hoists used solely for lifting material directly into a machine. In these hoistways subsections (3) and (4) shall not apply.

(6) Hoistways of hoists which are not used for carrying persons and into or from which goods or materials are not loaded or unloaded except at a height of not less than 2 ft. 9 in. above the level of the floor or ground where the loading or unloading is performed. In these hoistways subsection (4) shall not apply, but this exemption shall not apply to any gate unless there is a fixed enclosure not less than 2 ft. 9 in. in height below the bottom of the gate and reaching down to the level of the floor or ground; and every gate to which this exemption does apply (i) shall be fitted with an efficient device to secure that the cage or platform cannot be raised or lowered unless the gate is closed, and will come to rest when the gate is opened or, (ii) where it is not reasonably practicable to fit such a device, shall be kept closed and fastened except when the cage or platform is at rest at the gate.

(7) Hoists which are not connected with mechanical power and which are not used for carrying persons, and the enclosures of the hoistways of such hoists. In these hoists subsection (5) shall not apply.

(8) Hoists mainly used for raising materials for charging blast-furnaces or lime-kilns. In these hoists, subsection (3), in so far as it requires a gate at the bottom landing, shall not apply; neither subsection (4) nor subsection (5) shall apply; and paragraph (*b*) of subsection (7) shall not apply.

(9) Hoists used for the raising or lowering or tipping of railway rolling-stock. In these hoists, subsection (3), in so far as it requires the recognized entrances to the enclosure, being entrances through which the rolling-stock passes, to be fitted with gates, shall not apply; neither subsection (4) nor subsection (7) (*b*) shall apply, but so far as is reasonably practicable, means shall be provided at such entrances to the enclosure to prevent any person falling down the hoistway or being struck by any moving part of the hoist.

(10) Drop-pit hoists used for raising or lowering wheels detached from railway rolling-stock. In these hoists subsections (3) to (7) shall not apply.

(11) Hoists in the case of which the doors of the hoistway are of solid construction and the interior surfaces of the said doors and of the hoistway opposite to any side of the cage in which there is an opening are, throughout the height of travel of the cage, smooth and flush with each other and not more than half-an-inch, measured horizontally, from the edge of the floor of the cage. In these hoists subsection (7) (*b*) shall not apply.

The Hoists Exemption (Amendment) Order, 1946, amends para. 11 above as follows—

The words "and not more than half-an-inch, measured horizontally, from the edge of the floors of the cage" are deleted and replaced by—

> "save for any recess designed for working purposes and not more than half-an-inch in depth, and handgrips not exceeding one inch in depth provided for closing doors and so constructed as to prevent trapping."

## Statutory Rules and Orders, 1908, No. 1312.

REGULATION 15.

Every switchboard, having bare conductors normally so exposed that they may be touched, shall, if not located in an area or areas set apart for the purposes thereof, where necessary be suitably fenced or enclosed.

No person except an authorized person, or a person acting under his immediate supervision, shall for the purpose of carrying out his duties have access to any part of an area so set apart.

REGULATION 17.

At the working platform of every switchboard and in every switchboard passageway if there be bare conductors exposed or arranged to be exposed when live so that they may be touched, there shall be a clear and unobstructed passage of ample width and height with a firm and even floor. Adequate means of access, free from danger, shall be provided for every switchboard passageway.

The following provision shall apply to all such switchboard working platforms and passageways, unless the bare conductors, whether overhead or at the sides of the passageways, are otherwise adequately protected against danger by devices or screens or other suitable means—

(*a*) those constructed for pressures below 650 volts shall have a clear height of not less than 7 ft. and a clear width, measured from bare conductor of not less than 3 ft.

(*c*) bare conductors shall not be exposed on both sides of the switchboard passageway unless either—

(i) the clear width of the passage is in the case of pressures not exceeding 650 volts not less than 4 ft. 6 in. measured between bare conductors, or

(ii) the conductors on one side are so guarded that they cannot be accidentally touched.

REGULATION 21.

Where necessary to prevent danger, adequate precautions shall be taken either by earthing or by other suitable means to prevent any metal other than the conductor from becoming electrically charged.

# APPENDIX II

## TABLE I

### Diameters and Breaking Strengths of 6 × 19 Ropes

| 1 | 2 | 3 |
|---|---|---|
| Diameter of Rope (in.) | Approx. Breaking Strength of Rope | |
| | Tensile Strength of Wire 70/80 tons per sq. in. (tons) | Tensile Strength of Wire 80/90 tons per sq. in. (tons) |
| $\frac{1}{4}$ | 1·5 | 1·7 |
| $\frac{5}{16}$ | 2·3 | 2·7 |
| $\frac{3}{8}$ | 3·3 | 3·8 |
| $\frac{7}{16}$ | 4·6 | 5·2 |
| $\frac{1}{2}$ | 6·0 | 6·8 |
| $\frac{9}{16}$ | 7·6 | 8·7 |
| $\frac{5}{8}$ | 9·4 | 10·7 |
| $\frac{11}{16}$ | 11·4 | 12·9 |
| $\frac{3}{4}$ | 13·6 | 15·4 |
| $\frac{13}{16}$ | 15·9 | 18·0 |
| $\frac{7}{8}$ | 18·5 | 20·9 |
| $\frac{15}{16}$ | 21·2 | 24·0 |

For six-strand Seale ropes of dual tensile strengths, having outer wires of 70/80 tons per sq. in. tensile strength and inner wires of 110/120 tons per sq. in. tensile strength, the approximate breaking strengths are as given in column 3 above.

## TABLE II

DIAMETERS AND BREAKING STRENGTHS OF 8 × 19 ROPES

| 1 | 2 | 3 |
|---|---|---|
| Diameter of Rope (in.) | Approx. Breaking Strength of Rope | |
| | Tensile Strength of Wire 70/80 tons per sq. in. (tons) | Tensile Strength of Wire 80/90 tons per sq. in. (tons) |
| $\frac{5}{16}$ | 2·2 | 2·5 |
| $\frac{3}{8}$ | 3·1 | 3·5 |
| $\frac{7}{16}$ | 4·3 | 4·8 |
| $\frac{1}{2}$ | 5·6 | 6·3 |
| $\frac{9}{16}$ | 7·0 | 8·0 |
| $\frac{5}{8}$ | 8·7 | 9·8 |
| $\frac{11}{16}$ | 10·5 | 11·9 |
| $\frac{3}{4}$ | 12·5 | 14·2 |
| $\frac{13}{16}$ | 14·7 | 16·6 |
| $\frac{7}{8}$ | 17·0 | 19·3 |
| $\frac{15}{16}$ | 19·5 | 22·2 |

For eight-strand Seale ropes of dual tensile strengths, having outer wires of 70/80 tons per sq. in. tensile strength and inner wires of 110/120 tons per sq. in. tensile strength, the approximate breaking strengths are as given in column 3 above.

# APPENDIX III*

## BREAKING LOADS OF SPECIAL STRAND ROPES

### TABLE I

BREAKING LOADS OF BEST PATENT STEEL ROPES
80–90 tons per in.$^2$

| Circumference (in.) | 5 × 27, 28, 29 Oval (Actual Tons) | 6 × 25 Flattened Strand (Actual Tons) |
|---|---|---|
| $1\frac{1}{2}$ | 5·8 | 7·4 |
| $\frac{5}{8}$ | 6·8 | 8·8 |
| $\frac{3}{4}$ | 8·0 | 10·0 |
| 2 | 10·7 | 13·1 |
| $\frac{1}{8}$ | 12·1 | 14·9 |
| $\frac{1}{4}$ | 13·8 | 16·6 |
| $\frac{3}{8}$ | 14·5 | 18·6 |
| $\frac{1}{2}$ | 16·2 | 20·7 |
| $\frac{3}{4}$ | 19·9 | 25·1 |
| 3 | 24·1 | 29·5 |
| $\frac{1}{8}$ | 26·2 | 32·0 |
| $\frac{1}{4}$ | 27·4 | 34·8 |
| $\frac{3}{8}$ | 29·7 | 37·5 |
| $\frac{1}{2}$ | 32·2 | 40·7 |
| $\frac{3}{4}$ | 37·3 | 46·6 |
| $\frac{7}{8}$ | 40·0 | 49·9 |
| 4 | 42·8 | 52·8 |
| $\frac{1}{4}$ | 48·7 | 59·2 |
| $\frac{3}{8}$ | 50·2 | 63·4 |
| $\frac{1}{2}$ | 53·4 | 66·1 |
| $\frac{3}{4}$ | 60·0 | 73·5 |
| 5 | — | 81·4 |
| $\frac{1}{8}$ | — | — |
| $\frac{1}{4}$ | — | 90·2 |
| $\frac{1}{2}$ | — | 98·8 |
| $\frac{3}{4}$ | — | 107·2 |
| 6 | — | 116·7 |

* Reproduced by permission from British Standard Specification No. 621 : 1935, *Wire Ropes of Special Construction for Engineering Purposes*, copies of which may be obtained from the British Standards Institution, 28 Victoria Street, London, S.W.1.

## TABLE II

### Breaking Loads of Special Improved Patent Steel Ropes
90–100 tons per in.[2]

| Circumference (in.) | 5 × 27, 28, 29 Oval (Actual Tons) | 6 × 25 Flattened Strand (Actual Tons) |
|---|---|---|
| 1½ | 6·4 | 8·3 |
| ⅝ | 7·7 | 9·7 |
| ¾ | 9·0 | 11·0 |
| 2 | 11·9 | 14·6 |
| ⅛ | 13·6 | 16·4 |
| ¼ | 15·3 | 18·5 |
| ⅜ | 16·2 | 20·4 |
| ½ | 18·1 | 23·0 |
| ¾ | 22·3 | 27·8 |
| 3 | 26·9 | 32·7 |
| ⅛ | 29·4 | 35·7 |
| ¼ | 30·6 | 38·7 |
| ⅜ | 33·2 | 41·7 |
| ½ | 36·0 | 45·1 |
| ¾ | 41·7 | 51·8 |
| ⅞ | 44·7 | 54·8 |
| 4 | 47·8 | 58·4 |
| ¼ | 54·4 | 65·4 |
| ⅜ | 56·2 | 70·3 |
| ½ | 59·6 | 73·3 |
| ¾ | 67·0 | 81·1 |
| 5 | — | 90·1 |
| ⅛ | — | — |
| ¼ | — | 99·6 |
| ½ | — | 109·2 |
| ¾ | — | 118·6 |
| 6 | — | 130·8 |

## TABLE III

### Breaking Loads of Best Plough Steel Ropes

100–110 tons per in.[2]

| Circumference (in.) | 5 × 27, 28, 29 Oval (Actual Tons) | 6 × 25 Flattened Strand (Actual Tons) |
|---|---|---|
| $1\frac{1}{2}$ | 7·1 | 9·0 |
| $\frac{5}{8}$ | 8·4 | 10·6 |
| $\frac{3}{4}$ | 9·9 | 12·1 |
| 2 | 13·2 | 15·9 |
| $\frac{1}{8}$ | 15·0 | 17·7 |
| $\frac{1}{4}$ | 17·0 | 20·1 |
| $\frac{3}{8}$ | 18·0 | 21·8 |
| $\frac{1}{2}$ | 20·1 | 25·1 |
| $\frac{3}{4}$ | 24·7 | 30·5 |
| 3 | 29·8 | 35·7 |
| $\frac{1}{8}$ | 32·4 | 38·9 |
| $\frac{1}{4}$ | 33·8 | 42·1 |
| $\frac{3}{8}$ | 36·7 | 45·3 |
| $\frac{1}{2}$ | 39·7 | 49·1 |
| $\frac{3}{4}$ | 46·0 | 56·4 |
| $\frac{7}{8}$ | 49·4 | 60·4 |
| 4 | 52·9 | 63·9 |
| $\frac{1}{4}$ | 60·1 | 71·6 |
| $\frac{3}{8}$ | 62·0 | 78·5 |
| $\frac{1}{2}$ | 65·9 | 79·5 |
| $\frac{3}{4}$ | 74·1 | 89·5 |
| 5 | — | 99·0 |
| $\frac{1}{8}$ | — | — |
| $\frac{1}{4}$ | — | 109·9 |
| $\frac{1}{2}$ | — | 120·9 |
| $\frac{3}{4}$ | — | 130·9 |
| 6 | — | 142·5 |

## TABLE IV

BREAKING LOADS OF SPECIAL IMPROVED PLOUGH STEEL ROPES
110–120 tons per $in.^2$

| Circumference (in.) | 5 × 27, 28, 29 Oval (Actual Tons) | 6 × 25 Flattened Strand (Actual Tons) |
|---|---|---|
| 1½ | 7·7 | 9·8 |
| ⅝ | 9·2 | 11·5 |
| ¾ | 10·9 | 13·2 |
| 2 | 14·4 | 17·1 |
| ⅛ | 16·5 | 19·2 |
| ¼ | 18·6 | 21·8 |
| ⅜ | 19·7 | 24·3 |
| ½ | 22·0 | 27·1 |
| ¾ | 27·0 | 32·8 |
| 3 | 32·6 | 38·6 |
| ⅛ | 35·5 | 42·0 |
| ¼ | 37·0 | 45·8 |
| ⅜ | 40·2 | 49·2 |
| ½ | 43·5 | 53·7 |
| ¾ | 50·5 | 61·0 |
| ⅞ | 54·1 | 65·5 |
| 4 | 57·9 | 69·3 |
| ¼ | 65·9 | 77·6 |
| ⅜ | 68·0 | 84·3 |
| ½ | 72·3 | 86·2 |
| ¾ | 81·1 | 97·2 |
| 5 | — | 107·7 |
| ⅛ | — | — |
| ¼ | — | 119·5 |
| ½ | — | 130·8 |
| ¾ | — | 142·0 |
| 6 | — | 154·3 |

# APPENDIX IV

## INTERFERENCE WITH WIRELESS RECEPTION DUE TO ELECTRIC LIFTS

**Sources of Interference.** The items of lift equipment which may cause interference with wireless reception consist of the driving motor, which gives a continuous noise in the receiver, and the controller, giving noises of the "click" type. The radiated interference is further increased because the interfering sources are connected to the car flexible cable and to the wiring between gate interlocks and the controller and the supply mains. The latter wiring is frequently in steel conduit, but the flexible cable normally has no metallic protection. Interference may thus reach the wireless receiver by way of the electric mains or by direct radiation from the motor and controller, from wiring in the well, or from the flexible cable acting as a radiating aerial. In addition, the metal enclosure of the well is frequently inadequately earthed, and this gives rise to voltages along the well which may cause serious interference.

The radiated motor interference is less than that due to the control circuits if the motor is properly maintained, the motor noise being negligible if a motor generator set is employed, whilst even for d.c. motors with direct mains supply the noise is generally less than the controller noise except where the motors are not efficiently maintained. Auxiliary motors such as brake or door opening motors are also possible sources of interference.

Controller interference is mainly due to the circuits controlling the driving motor contactor coils and the brake coil, these being most troublesome when supplied direct from the mains. All circuits for remote control, particularly those entering the flexible cable, form systems which give a high frequency radiation, whilst the brake magnet is also a radiating source. A.c. controllers usually cause very little disturbance.

The interference from the sources mentioned above appears also as interfering voltages at the supply terminals, thus causing mains-borne interference.

**Methods of Suppression.** Two methods are employed to prevent interference at the source—

(*a*) By preventing the generation of the interference.

(*b*) By limiting the effect of the interference and preventing its radiation or its passage to the power supply mains.

The first method can often be adopted on the controller switches by incorporating spark quenching circuits, but in the majority of cases it is necessary to prevent the interference from leaving the source. This is done by screening as far as radiation is concerned, and by the use of filter circuits to prevent the passage of the disturbing radio-frequency currents to the supply mains.

**Lift Motors.** Most interference is caused by commutator machines and is usually worse if sparking is present at the commutators. In the case of the smaller d.c. motors, condensers alone often give adequate suppression. Two condensers (either 2 $\mu$F. or 4 $\mu$F.) joined in series across the supply mains are usually sufficient. The centre point of the condensers must be connected to the frame of the machine which should be efficiently earthed. A greater degree of suppression is often obtained, however, when the condensers are connected directly to the brushgear with the leads as short as possible. For the larger d.c. machines two radio-frequency chokes may be necessary in addition to condensers. The chokes should be about 600 $\mu$H., connected one in each main lead to the motor, either on the mains or motor side of the condensers. If the motor impedance is low and the mains impedance high, the chokes should be fitted on the motor side of the condensers and vice versa.

A.c. motors, with the exception of commutator motors, do not usually cause as much interference as d.c. motors. Suppression in the case of a.c. commutator motors is effected by a choke condenser filter similar to that described for d.c. motors. The single-phase repulsion-induction motor is an interfering type, however, and since the armature is normally short-circuited, the fitting of condensers across the brushes cannot effect a cure. It is therefore necessary to insert condensers and chokes in the mains leads as for d.c. motors. Induction motors of both the squirrel-cage and slip-ring types do not usually give trouble if they are properly maintained.

**Control Circuits, etc.** The radiated interference due to the control circuits entering the car flexible cable may be suppressed by chokes of about 6 mH. connected in each lead of the flexible cable both at the car and the controller ends. In addition, condensers of 0·5 $\mu$F. or 1 $\mu$F. may be connected from each lead to earth on the flexible cable side of the chokes. Suppression may sometimes be obtained by mounting the chokes at the half-way box in the well instead of in the car, whilst the chokes at the controller end may often be omitted. The former method is generally necessary when the control circuits are energized from the full mains voltage.

Control circuits such as gate interlocks which do not enter the flexible cable are treated in a similar manner, filters being required at the operating switch and the relay coil. If the wiring is in conduit or screened, the chokes may often be omitted from the filters.

The coils of the circuit-breaker and controller contacts should be fitted with condensers of 1 $\mu$F. or 2 $\mu$F. capacitance connected between each end of the coil and earth. It is often advantageous to connect condensers up to 4 $\mu$F. across the car switch contacts. Interference due to the brake magnet coil can be suppressed by an arc suppressor of the rectifier type. The metal work of the well should be efficiently earthed.

Any interference passing into the mains supply can be reduced by a choke condenser filter in the mains.

## Bibliography

A. S. Angwin: Institution of Post Office Electrical Engineers printed paper No. 137.

A. J. Gill and S. Whitehead: "Electrical Interference with Radio Reception." (*I.E.E. Journal*, Vol. 83, p. 345.)

A. Morris: "Interference of Electrical Plant with the Reception of Radio Broadcasting." (*I.E.E. Journal*, Vol. 74, p. 245.)

B.S. Code of Practice C.P. 1006—"General Aspects of Radio Interference Suppression." (British Standards Institution.)

# APPENDIX V

## NOTES ON WEAR OF WIRE ROPES*

The recommendations regarding working loads given in Appendices II and III and those relating to minimum diameters of sheaves, pulleys and drums stated in Chapter III afford sufficient margin of safety, taking into account bending and reasonable rope life. In the design of new lifts care must be given to securing this reasonable rope life by requiring sheaves and pulleys to be of adequate diameter and to have grooves of correct size and shape, ensuring that sheaves and pulleys are correctly aligned, that the working load is reasonable and, as far as possible, that reverse bends in the roping system are avoided.

In selecting a wire rope, consideration should be given to the diameter of the single wires forming the strand. Wire less than 24 s.w.g. (0·022 in.) allows little wear and 14 s.w.g. (0·080 in.) is about the largest which should normally be used. A range of 22 s.w.g. (0·028 in.) to 16 s.w.g. (0·064 in.) is considered good practice, and on this basis round strand 6/19 ropes should be between $1\frac{3}{8}$ in. and 3 in. circumference. Where considerable wear is anticipated it is advisable to install a rope with large diameter outer wires, and this suggests a rope of Seale construction. The construction of a Lang's lay rope, however, exposes a greater length of wire to wear, but Lang's lay has a greater tendency to untwist than ordinary lay ropes. Provided care is taken in handling, this feature is not a disadvantage for lift work, as both ends are secured against rotation. Preformed Lang's lay rope is, of course, not subject to untwisting.

Wire ropes fail chiefly because of abrasive wear of the outer wires or fatigue of the material. The flats on the outer wires can readily be seen, and it is of interest to note that a flat of three-quarters of the diameter of the wire in width reduces the sectional area of the wire by approximately 10 per cent. If there is no internal corrosion or fatigue the inner wires form a

* See B.S. Handbook No. 4—" Lifting Tackle."

reserve of strength which is not affected by the wear on the outer wires, and this reserve is greater the larger the number of layers in the strand.

It is good practice to replace any rope in which a given number of wires in a specified length are broken. The number of broken wires which necessitate the replacement of a rope should bear a relation to the total number of wires in the strand and the proportion of outer to inner wires. The Statutory Rules and Orders under the Docks Regulations, Section VII, clause 20 (*c*), provide—

"No wire rope shall be used in hoisting or lowering if in any length of eight diameters the total number of visible broken wires exceeds 10 per cent of the total number of wires, or the rope shows signs of excessive wear, corrosion, or other defect which, in the opinion of the person who inspects it, renders it unfit for use."

The 1945 Draft Revision of the Building Regulations, Part III, clause 58 (2) provides—

"No wire rope shall be used in raising or lowering or as a means of suspension if in any length of ten diameters the total number of visible broken wires exceeds 5 per cent of the total number of wires in the rope."

In the case of normal six-strand lift ropes, 10 per cent of the total number of wires in eight diameters is equivalent to one wire in twelve in a length equal to one lay, while 5 per cent of the total number of wires in ten diameters is equivalent to one wire in thirty in a length equal to one lay. In the majority of ropes the visible broken wires are outers, but the distribution of the wires is important; there is a considerable difference between broken wires equally distributed between six strands and broken wires all in one or two strands. In the latter case a much smaller number of broken wires may render the rope dangerous.

It will be clear that a greater proportionate number of equally distributed broken outer wires can be tolerated in a 6/37 rope with a total of 222 wires, of which 108 are outers, than in a 6/19 rope with 114 wires, of which 72 are outers. In a 6/37 rope the reserve strength due to the inner wires is 51 per cent, and in a 6/19 rope only 37 per cent.

When inspecting a worn rope the number and distribution of

the broken wires and the amount of visible wear should be taken into account, and an estimate made of the percentage reduction from the original rope strength. If the original Factor of Safety was 12, then a reduction to 83 per cent of the original strength reduces the Factor of Safety to 10, and a reduction to 66 per cent reduces the factor to 8.

In estimating the strength of a worn rope it is convenient to relate the visible wear on the outer wires as equivalent to a reduction in the total number of wires in the rope, subtracting from the total so obtained the number of broken wires in any one lay. The equivalent reduction in the total number of wires can then be calculated as a percentage of the original number of wires. As an example, consider a worn 6/19 rope which has an estimated 20 per cent wear on the outer wires and 5 broken wires in one lay. This rope construction has 42 inner wires and 72 outer wires, making a total of 114 wires. When the rope is new each broken wire results in a percentage loss in strength of 0·877, and five broken wires in a loss of 4·38 per cent. As the wires are now 20 per cent worn, the loss due to these five is $\frac{80}{100}$ of 4·38 per cent $= 3{\cdot}5$ per cent. So far as the wear of the wires is concerned, a 20 per cent wear on the outers is equivalent to a loss of $\frac{20}{100} \times 72$ wires $= 14{\cdot}4$ wires, which is equivalent to 99·6 good wires remaining. Hence, the remaining percentage rope strength due to 20 per cent wear on the outers is $\frac{99{\cdot}6}{114} \times 100 = 87{\cdot}3$, and as the percentage reduction due to broken wires is 3·5, the total remaining percentage strength is therefore 83·8.

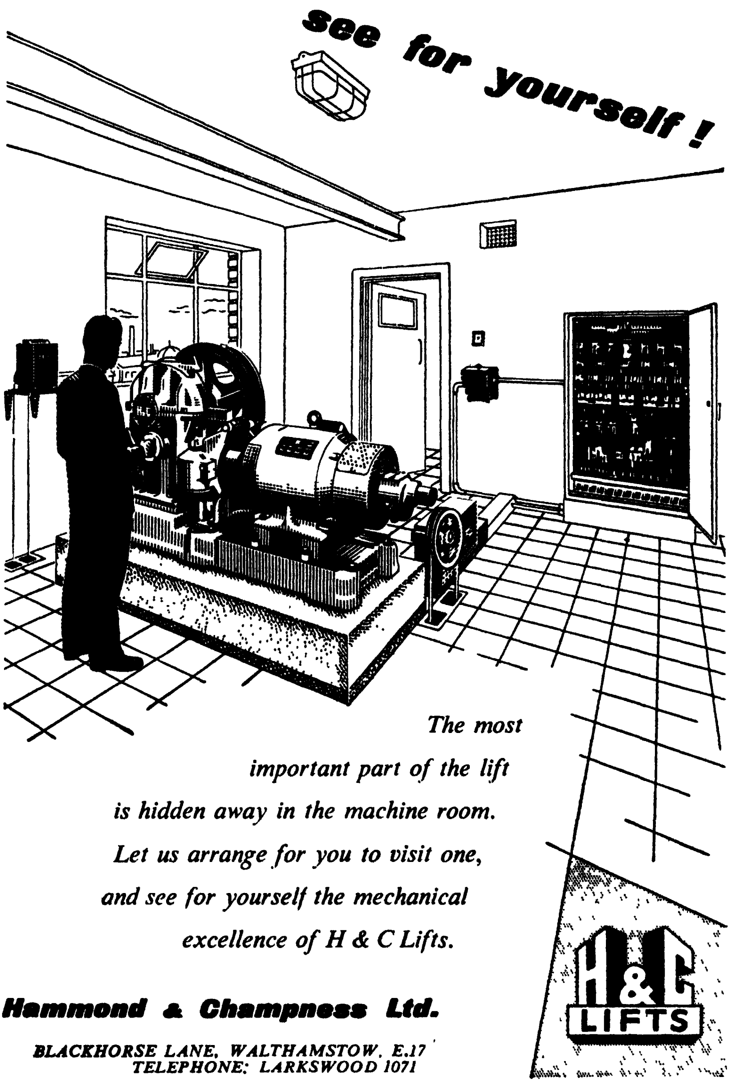
During operation, shock loading should, as far as possible, be avoided and gradual acceleration adds materially to the life of a wire rope. Where a rope is under constant load it is a good plan, if possible, to vary the position of the load when periodically at rest, over-night, or at week-ends. The same portion of the rope should not always rest on a sheave if its position can be varied when left standing.

Wire ropes are fully lubricated during manufacture to reduce friction between the wires and to prevent corrosion. In service

this lubricant is gradually squeezed out, and it should, as far as possible, be replaced by periodical external applications. Where ropes pass over a sheave drive, however, the sheave grooves and the outer wires of the rope should be kept free of lubricant.

Where rapid wear is evident every effort should be made to ascertain the cause. Both sheaves or pulleys which do not revolve freely and grooves worn so that the ropes "bottom" cause abnormal wear. The method of roping and particularly the number of rope bends considerably affect rope life. The material and construction of the ropes and the relative hardness of the ropes and sheaves are important in minimizing wear. Probably the most important single factor in ensuring a satisfactory rope life is the reduction of the bending stress by employment of sheaves and pulleys of adequate diameters. Considerable wear may result if the ropes bind on the sides when leading on and off the sheave and pulleys. The number of normal stops made and the number of starts and stops due to "inching" by an inefficient attendant are important factors in rope life. High rates of acceleration and retardation which may cause slip will result in rope troubles as also will a badly adjusted brake or unequal loading on individual ropes. Insufficient internal lubrication may cause rusting and breaking of the inside wires.

# INDEX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